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ART. XII.—*Origin of Coral Reefs and Islands;* by JAMES D. DANA. With a map (Plate II).

THE Presidential Address of Dr. Archibald Geikie, Director-General of the Geological Survey of Great Britain, before the Royal Physical Society of Edinburgh in 1883,* reviews the subject of the origin of coral reefs and islands. In the course of the discussion, the author sustains and enforces the objections which have been presented by others, and concludes that "the existence of such reefs is no more necessarily dependent on subsidence than on elevation." The existing state of doubt on the question has led the writer to reconsider the earlier and later facts, and in the following pages he gives his results.† That both sides may be fairly before the reader, the views of Darwin and the evidences in favor of his theory are first considered, and afterwards the arguments that have been urged against it. Part of the objections are based on misunderstandings of the facts, and hence a general presentation of the subject has been thought necessary.

* Proceedings Edinb. Roy. Phil. Soc., viii, 1, 1883.

† The writer's account of his original observations is contained in his Wilkes Expedition Geological Report, 1849 (756 pp. 4to), pages 29–154; and, less completely, along with a review of facts from other regions, in his Corals and Coral Islands, 398 pp. 8vo, 1872, 1875.

Part I.—The Darwinian Theory and its Evidences.

1. According to the Darwinian theory, islands with fringing reefs have been often changed through a slow subsidence of the region into islands with barrier reefs; and, as the last summit of the sinking land disappeared, the latter have become atolls, that is, barrier reefs enclosing simply a piece of the ocean (or a lagoon). Darwin added to this conclusion, a *second*, in view of the wide distribution of atolls and their relations to other islands: that the subsidence indicated involved the whole central Pacific, besides other large areas. He also expressed the opinion that a Pacific continent had disappeared through the subsidence. The proofs of the first and the second conclusions are partly different and should not be confounded. The third is no necessary part of the general theory, was not adopted in my Report, and need not be further considered.

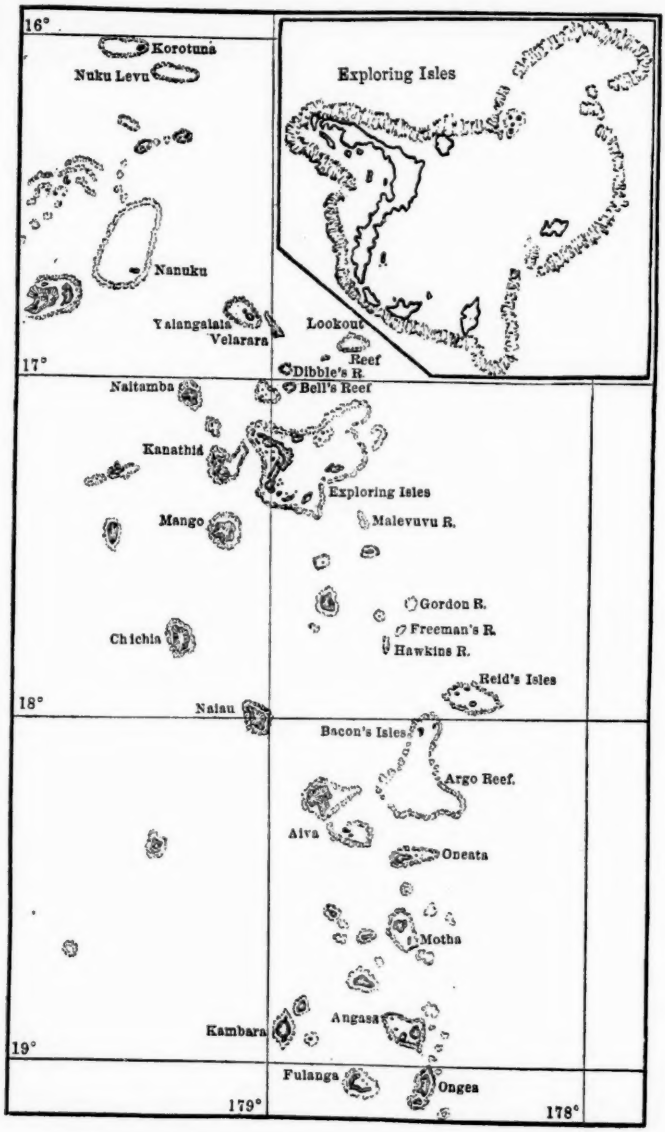
2. Darwin did not hold that atolls were necessarily evidence of a subsidence *now* in progress, but allowed that in some regions they may have reached a state of rest, and may perhaps have undergone an elevation since the cessation of the subsidence; and also that subsidence and elevation may have alternated.

3. Darwin found what he believed to be *almost certain proof of subsidence* in the features of the large barrier-islands and atolls. He perceived in the rocky islets that dot the great interior lagoon-like waters of the Gambier group, Hogoleu, and other similar barrier-islands of the Pacific, and the general resemblance of such islands to atolls, strong evidence, "leaving scarcely any doubt on the mind," that the islets were the emerged points of *sunken* lands; that such barrier-islands were no less lagoon islands than Keeling atoll (the atoll which he investigated); and if evidence of subsidence, the atoll was proof of further subsidence, that is, one that had continued to the disappearance of the sinking peaks.

The evidence which had satisfied him was satisfactory to me when I first learned of his views in Australia (in 1839), after a cruise among the Paumotu atolls and the Tahitian and Samoan reef-regions; and more decidedly so later, when I had been among the Friendly, Feejee and other Pacific Islands.

That the argument may be appreciated I here introduce a map of the eastern half of the Feejee Archipelago.* Several of the great barrier reefs in this map, 10 to 20 miles in length, have but one or two peaks of the sunken land remaining; Nanuku has but one little point near its southeastern angle, a mile of peak within a barrier island 200 square miles in area;

* Reduced from the general map of the archipelago in the Atlas of the Wilkes Expedition.



EASTERN PART OF THE FEJEE ARCHIPELAGO

Bacon's Isles are the last two little peaks of a still larger lagoon; and besides these and other examples of disappearing lands, a dozen of the easternmost islands are actual atolls—the last peak gone.

4. To this the chief of Darwin's arguments in his own view, another of like importance is added in my Report: *the existence of deep fiord-like indentations in the rocky coasts of islands, both of those inside of barriers and those not bordered by reefs.*

When making the ascent of Mount Aorai, one of the two high summits of Tahiti (September, 1839), where high narrow ridges, almost like a knife-edge along their tops, alternating with gorge-like valleys 1000 to 3000 feet deep, radiate from the central peaks but die out in a broad even plain at the shores, I was made to appreciate the consequence to such an eroded land of a partial submergence. At any level above 500 feet its erosion-made valleys would produce deep bays, and above 1000 feet, fiord-like bays, with the ridges spreading out in the water like spider's legs. Observing on the maps of the Marquesas Islands precisely this condition, it was a natural inference that the lands had undergone great subsidence, and perhaps were still subsiding.

With this criterion of subsidence in view, the evidence from the Gambier and Hogoleu islands is doubled in force: and that for the sinking of Raiatea of the Tahiti group, represented in fig. 3 of the plate of maps in Darwin's Coral Reefs, is as strong from each of the two enclosed islands as it is from the great breadth of the reef-grounds; and the same is true for Bolabola, another Tahitian island on the plate.

So it is also in the Feejees. The demonstration as to subsidence in the large barrier-island called the Exploring Isles, for example, is made complete by the form of the ridge of land along one side of the great barrier, and the positions of adjoining islets.

5. The general parallelism between the trends of coral islands and the courses of the groups of which they are a part, and the courses also of the groups of high islands not far distant, were regarded by Darwin as confirming his view that the coral islands were once high islands with bordering reefs.

6. Darwin uses also the argument that the larger coral islands have the diversity of form found in the barrier reefs of high islands; and also that they often have such groupings as would come from the sinking of a large island of ridges and peaks with encircling reefs. He describes the Maldives as one example of the latter, and the two loops of Menchikoff island in the Caroline archipelago, as another.

7. The depth of lagoons, and of the channels inside of large barrier reefs, afforded him further evidence of subsidence, it

being in many cases two to three times greater than the limiting depth (120 feet) of living reef-making corals.

8. The great depth of the ocean in near vicinity to the atolls is another source of evidence added.

9. He urged also, in supporting his views, the non-existence in the ocean now, and the extreme improbability of existence at any time, of submarine volcanoes or chains of mountains having their numerous summits within a hundred feet of the surface.

10. Darwin speaks of smallness of size in coral islands as a result of continued subsidence. In my Report I base an argument for subsidence on smallness in the proportion of dry land, and on smallness of size, when there is *gradation* toward either condition, and the seas beyond are free of islands. The facts bear on the general conclusion with regard to a Central-Pacific area of subsidence as well as on the fundamental point in the theory.

If an atoll-reef is not undergoing subsidence the coral and shell material produced that is not lost by currents serves: (1) to widen the reef; (2) to steepen, as a consequence of the widening, the upper part of the submarine slopes; (3) to accumulate, on the reef, material for beaches and dry land; and (4) to fill the lagoon.

But if, while subsidence is in progress, the contributions from corals and shells exceed not greatly or feebly the loss by subsidence and current waste, the atoll-reef, unable to supply sufficient debris to raise the reef above tide level by making beaches and dry land accumulations, would (1) remain mostly a bare tide-washed reef; (2) lose in diameter or size because the debris that is not used to keep the reef at tide-level is carried over the narrow reef to the lagoon by the waves whose throw on all sides is shoreward; (3) lose in irregularity of outline and thus approximate toward an annular form; (4) lose the channels through the reef into the lagoon by the growth of corals and by consolidating debris; and (5) become at last a small bank of reef-rock with a half obliterated lagoon-basin.

The Pacific contains reefs of the three kinds: (1) atolls with much of the reef under trees and shrubbery; (2) others, of large and small size, with the reefs mostly or wholly tide-washed; (3) others only two or three square miles in area, without lagoons. Further, the kinds are generally grouped separately and gradationally. (1) The islands of the Paumotu and Gilbert archipelagos have usually half or more of the reef dry and green; (2) the northern Carolines and the northern Marshall Islands, and the eastern Feejees, although in part of large size, are mostly bare reefs; while (3) the islands of the Phœnix Group, of the equatorial Pacific east of the line

of 180°, are, with one exception (Canton or Mary), not over four miles long. The three more southern of the Phœnix Islands (see Map, Plate II), Gardner's, Hull's and Sydney, between 4° 25′ S. and 4° 35′ S., are two to four miles long and have lagoons; five, including Phœnix, Birnie's and Kean's, between 3° 10′ S. and 3° 30′ S., and Howland and Baker's north of the equator, are a mile and a half and less in length, and have depressions at centre but no lagoons. The depressions contain guano, and one of them, Kean's, has much gypsum mixed with the guano;* Kean's and Phœnix have a foot or two of water at high tide, the tide rising 6 feet. Another of the number, Enderbury's, is three miles long and has a half-dried lagoon which is very shallow and has no growing corals.† To the north of these islands for fifteen degrees of latitude, the sea is an open one, and in the next ten degrees, to the line of the Hawaian Chain, the only islets not marked doubtful are "Coral Reef, Awash" and Johnston Island.

A similar gradation in size takes place in the Ellice, Ratack and many other groups of the ocean. Smallness of size, and dried lagoon basins, with occasionally a deposit of gypsum from evaporated sea-water, are just the result that should have come, by the Darwinian theory, from subsidence; and gradation in size from gradation in the amount of subsidence. The positions of the Union, Gilbert, Ratack and Ralick Groups with reference to the Phœnix Group are shown on the Map, Plate II. All of the islands on the map are coral islands, and nearly all atolls; and the part of the encircling reef marked by fine dots is under water at high tide.

Adopting this view of the origin of these smallest of coral-made islands, I readily accepted Darwin's second conclusion as to a great central oceanic area of subsidence. The further inference, also, was deduced, for reasons stated in my Report, that the greatest amount of subsidence took place along a belt stretching southeastward from the southern half of Japan and passing south of the Marquesas Group toward Easter Island, and a line was drawn on a map among its illustrations representing the course of "the axial line of greatest depression."‡

* J. D. Hague, Amer. Jour. Sci., II, xxxiv, 242. Mr. Hague, in his valuable paper on the Guano Islands of the Central Pacific, mentions the existence of a bed of gypsum two feet thick under the guano of Jarvis Island, another small equatorial island, eleven degrees east of the Phœnix Group.

† Baker's Island has a height of 22 feet according to Mr. Hague, showing, he says, some evidence of elevation; and Enderbury's I found to be 18 feet in height, from which I inferred some elevation. But Howland's, Birnie's, McKean's, Phœnix, Gardner's, Hull's and Sydney are not higher than ordinary atolls would be in a sea of 6-foot tide.

The facts with regard to the "Reef" on the map, in long. 175° W. and lat. 2° 40′ S., I have been unable to learn.

‡ Report, pp. 399 and 432, and map between pages 8 and 9.

This line is reproduced on a chart of the World, in my Manual of Geology, where it is lettered A′ A′.

These deductions have been apparently sustained by the soundings of the Tuscarora and Challenger in 1874, 1875 and 1876. The soundings of the Tuscarora through the Phœnix Group in 1875, on its route from the Sandwich Islands to the Feejees (under the command of J. N. Miller, U. S. N., by the order of the U. S. Hydrographic Bureau), are shown on the map of the central Pacific herewith published (Plate II).

The soundings about these islands prove (1) that the islands are situated within the deep 3,000–4,000-fathom area of the ocean; and appear to indicate also (2) that along lines *transverse* to the trend of the islands (or to the direction of trend in other groups to the west), mean submarine slopes of 1 : 1·5 to 1 : 7 exist; while in the direction of the trend, the slopes are much less. The slope of 1 : 1·5, or that of the angle 33° 41′, is nearly the maximum slope of the sides of Cotopaxi, Mt. Shasta and several other volcanic summits of Western America.

The facts are these.

Half way between Sydney and Birnie's islands, 60 English miles apart, a depth of 3000 fathoms (18,000 feet), was found. Off Enderbury's Island (40 miles northeast of Birnie's), (1) a depth of 2835 fathoms was obtained 20 miles to the southwest; (2) of 880 fathoms 2½ miles to the southwest; (3) of 1991 fathoms 3 miles to the northeast; and (4) of 2370 fathoms, 11 miles to the northeast. The mean slopes to the southwest, calculated from the soundings 1 and 2 are 1 : 6 and 1 : 3; and to the northeast, from 3 and 4, 1 : 1·5 and 1 : 4, fourteen miles south*east* of Hull's Island, at right angles to the above direction, a depth of 935 fathoms was found, which gives the slope 1 : 13.

Further evidence as to the submarine slopes about equatorial coral-reef islands is afforded by soundings made under the direction of the British Admiralty, near the very small Swain's Island, at the south end of the Union Group (see map); and others, by the Tuscarora under Commander Miller, in 1876, near the Danger Islands, about five degrees east of Swain's. Off Swain's Island, two soundings, one south of it and the other east, (the two directions at right angles to one another and the latter not diverging far from the trend of the other islands of the Union Group), give the slopes 1 : 7 and 1 : 13. Off Danger Island, as Commander Miller's Report states,* the depth of 660 fathoms was obtained half a mile (nautical) off the southwest corner of the reef near Southeast island, and 985 fathoms one mile east of the reef,—corresponding to slopes 1 : 1 and 1 : 0·75. 1 : 1 is a steeper slope than occurs even in small dry-made cinder cones; and 1 : 0·75 (53° 8′) is steeper still.

* I am indebted for the soundings about Danger Islands to Commander J. R. Bartlett, Superintendent of the U. S. Hydrographical Bureau.

The above facts are sufficient to authorize the drawing of the bathymetric lines for 1000, 2000 and 3000 fathoms *quite closely* about the islands of the Phœnix Group, and to give the areas a northwest-southeast elongation, corresponding with that of the neighboring Pacific islands to the west, as on the accompanying map, Plate II.*

It follows from the above mentioned facts that the deep-water areas adjoining the Phœnix Group, named provisionally by Petermann† the "Hilgard depths" and the "Miller depths," are parts of one large area 1200 miles broad. The greatest depth obtained in the part of the area southwest of the group (400 miles broad) is 3305 fathoms, and in the part northeast, 3448 fathoms.

Again: the soundings of the Tuscarora of 1875 here cited, taken in connection with those of the same vessel in 1874, under Commander George F. Belknap, along a line from the Sandwich Islands westward to Japan (mostly between the parallels of 20° and 25°), suggest the further conclusion: that the deep-sea area of the central equatorial Pacific, in which the Phœnix Islands stand, extends northwestward toward Japan, and that it was crossed by the Tuscarora between 171° E. and 150° E, where were found depths from 3009 to 3273 fathoms (with some alternations of smaller depths that isolated areas may account for). It is also probable that the soundings of the Challenger east of Japan between 153° E. and 143° E. and just northwest of those of the Tuscarora, were within the same deep-sea area. If this be so, a long deep-water area or trough extends from Japan southeast-

* The line on the map for 1000 fathoms is a simple dotted line; that for 2000 fathoms, - - - - -; for 3,000 fathoms, – – – –.

† Geogr. Mittheil., 1877, page 125 and plate 7. The deep areas along the lines of soundings, were named by Petermann on his very valuable bathymetric map of the Pacific simply to facilitate reference.

The bathymetric lines about the islands, on the accompanying map, Plate II, have an unreasonable degree of regularity. But with no facts to indicate the actual irregularities, none could be reasonably introduced. The trends given them are the same as on Petermann's map. The actual steepness of slope is probably not exaggerated for either of the islands. If similar slopes exist about the smaller islands in other parts of the ocean, the final bathymetric map of the Pacific will have a very different aspect from that presented by the maps hitherto published, and the Central Pacific a much greater mean depth. About Wakes Island, a small atoll in latitude 19° 11′, standing alone in the ocean six degrees north of the Ralick Chain, the width of the area enclosed by the 2000 fathom line, as drawn on Petermann's bathymetric map, is nearly 100 nautical miles, while, in view of facts at the Phœnix Group, the actual width is probably not over 10 or 15 miles.

With but four lines of soundings for the part of the great Pacific Ocean, within 35 degrees of the equator, the author of a bathymetric map has to rely chiefly on his judgment or conjecture for the larger part of the surface. There are many great problems in physical, geological and biological science that would be elucidated by the facts which a thorough bathymetric survey of the ocean would afford; and the work is large and important enough to call for aid from each of the great nations of the world. Thus far, for the Pacific Ocean, the United States is first in the amount of work done.

ward through the Central Pacific, conforming well to the suggestion of the Darwinian theory; and corresponding in direction approximately to the "axial line of greatest depression" referred to above—the line AA on the accompanying map.

As regards the rest of the Central Pacific between the above defined 3,000–4,000-fathom belt and the Hawaian chain, the depths sounded by the Tuscarora are, with few exceptions, over 2400 fathoms; two-thirds of them are over 2750 fathoms, and a fifth (out of the fifty-five in this area) over 3000.*

11. Since a fringing reef is, by the theory of Darwin, the first stage in the origin of an atoll, it was naturally regarded by him as, in general, evidence of little or no subsidence, and even, at times, of elevation. But since (1) bold shores are an occasion for narrow reefs and for their absence; (2) submarine volcanic disturbances and eruptions about volcanic lands would destroy living reefs, or retard their progress where begun; (3) islands of active volcanoes have small or no reefs; and (4) abrupt subsidences of only 120 feet would put reef corals below a surviving depth and so lead to the beginning of a new reef, I was led to regard the evidence from a fringing reef for no, or little, change of level, as of very doubtful value. But the doubts, while making such evidence generally useless, do not affect the value of the preceding arguments for subsidence. Darwin used the evidence from fringing reefs only to mark off the limits of the area of Central-Pacific subsidence to which his coral-island theory had led him; and the same limits essentially are reached notwithstanding the doubt. Instead of concluding that the region along these limits was one of recent elevation or at least

* The same two lines of soundings by the Tuscarora suggest the existence of a second long deep-sea belt or trough in the Central Pacific just south of the Hawaian chain. This supposed trough was crossed by this vessel in 1875 between the parallels of 13° N. and 18° N. ("Belknap depths"), and in 1874 between the meridians of 172½° W. and 177½ W. (the "Ammen depths"); the greatest depth found on the former line is 3125 fathoms, and on the latter 3106 fathoms. Should the existence of these two troughs be sustained, the region between them would be a Central-Pacific plateau; having in it, along the 1875 line of soundings, depths of 2972 to 1325 fathoms, and along that of 1874, depths of 2836 to 1108 fathoms; the shallower portion is near the middle of each line of soundings, has a great descent (6,000 to 9,000 feet) on either side—suggesting the idea of a central ridge. Over this plateau-area, there are, south of the Hawaian chain, two or three small coral islands, and farther eastward, the Palmyra, Kingman, Washington, Fanning and Christmas reefs and islands which, although coral structures, make the idea of a central ridge in this part for 600 miles almost a manifest fact. Farther east, the Marquesas islands are in the same range. The deep belt lying on the south side of the plateau diminishes in depth to the eastward, the Challenger soundings from the Sandwich Islands to Tahiti finding no depth in the course of this belt greater than 2750 fathoms; but the belt on its north side may continue eastward of the Challenger route. Many more lines of soundings are needed to substitute sure conclusions for the above suggestions.

The existence in the ocean of parallel belts of deeper and shallower waters, such as are here inferred to exist, and such as are actually indicated by the parallel lines of high islands and atolls, is in accordance with the facts over the continents.

of no subsidence, I was led to speak of it as one either of no subsidence or of less subsidence than over the central area referred to. The difference between us is small.

12. The true value of fringing reefs as evidence in the question of change of level should be appreciated in this discussion, as is apparent from the objections to Darwin's theory which have been urged; and I mention a few facts from the Pacific islands in its elucidation.

On Darwin's map, the Marquesas group is left uncolored, which means doubtful as to subsidence or not. The Tahitian group (Society Islands) is colored blue, that is, it is included within the area of coral-reef subsidence. The Navigator or Samoan Islands are colored red, or placed in the area of elevation; the Feejees, blue; the Sandwich Islands, red. The facts are these.

The Marquesas Islands are an example of absence of reefs to a large extent with only small reefs where any. But the shores are mostly too bold for reefs; and hence their smallness bears no testimony as to elevation. Along the bold shores, there are deep indentations and fiord-like bays separated in some cases by narrow ridges sometimes in spider-leg style; so that the proof of subsidence is positive, as explained in § 4.

Tahiti presents none of the Marquesan evidence of subsidence. Its erosion-made valleys, as already explained, die out at the broad shore plain, and the island is comparatively even in outline. I found over it, like Darwin before me, no evidence of elevation beyond one or two feet at the most. It has broad reefs; and the channel inside the barriers between Papieti and Toanoa (2 miles) has a depth of 3 to 25 fathoms. From the width of the reef, and the slope (6 to 8 degrees) of the land and of the lava streams outcropping in the sides of the valleys, supposing this slope to be continued under water, I made the probable subsidence 250 or 300 feet. A slope of 6 degrees, and a width of reef of half a mile, gives 240 feet for the depth of the reef at the outer edge.

The Samoan (or Navigator group) includes (beginning at the east) Rose Island (an atoll), Manua, Tutuila, Upolu and Savaii.

Manua has bold shores, a height of 2500 feet, and a narrow reef where any.* Tutuila is of the Marquesan type in its bold indented sides and this suggests a probable subsidence. Pango-

* With regard to Manua, Mr. J. P. Couthouy, of the Wilkes Exploring Expedition for two-thirds of its cruise, in his paper on Coral Formations (p. 50 of Proc. Bost. Soc. Nat. Hist., Jan. 1842) reported the occurrence of fragments of corals at a height of 80 feet "on a steep hill-side rising half a mile inland from a low sandy plain." I was not on Manua. I found on Upolu fragments of coral limestone and shells in the tufa of a tufa cone at a height of 200 feet, which had evidently been carried up by the erupting action of a slightly submerged vent. (Report p. 328.) The facts on Manua need further study.

pango Bay, in which we anchored in 174 feet water, has a length of three miles. The coral reefs are of the *fringing* kind where any occur. Upolu, a few miles west, has bold shores and small or no reefs for fifteen miles of its north shore, east of its middle; but elsewhere there are broad reefs—mostly 5000 to 8000 feet in width—and a very gentle slope (three to six degrees) in the land above—which is about the slope of its underlying lava streams. The great width of the reef seemed to be evidence of subsidence. But the absence on the north side of the island of a channel in the reef deep enough for any craft larger than canoes made it essentially a great fringing reef. A calculation from the width and land-slope gave about 260 feet for subsidence; but I add (on page 332 of my Report) my doubt as to any subsidence. The facts known are against any elevation.

Savaii, the largest island of the group, is a gently sloping volcanic mountain, much like its name-sake, Hawaii, in its features, with lavas looking as if not long out of the fire. It has a broad reef for only 6 or 7 miles of its east shore; elsewhere on the east and northeast sides the reefs are fringing or wanting; and on the southern and western sides mostly absent. No evidence of elevation, and nothing certain as to subsidence, has been reported from the island.

The large Feejee Group bears abundant evidence of subsidence in its very broad reef-grounds, barrier islands, and atolls. Fringing reefs, or barriers with very narrow channels, occur about some of the islands of the group; but in view of the facts that have been stated, these are useless as evidence either way.

Thus the conclusions as to the changes of level about these large Pacific groups south of the equator are not far from Darwin's, although fringing reefs and the volcanic character of the islands are thrown out of consideration, and other conditions exist of varied interpretation.

But cases of actual elevation occur in the Central Pacific about several smaller islands as proved by *elevated* coral reefs. These occur in the Austral and Hervey Islands south and southeast of Tahiti, and in the Tonga or Friendly Islands. In none of these, however, thus far reported is the elevation over 300 feet: and the amount varies greatly in adjoining islands of the same group, *some affording proof of no elevation.* Hence only local changes of level, not a general elevation, can be inferred.

To the north of the equator at the Sandwich Islands some elevated reefs occur. But the amount of elevation is small and is not general in the group. Moreover, the reefs are small, where any occur, and the largest island of the chain, volcanic

Hawaii, the easternmost, is mostly without reefs, as well as the larger of the westernmost islands, Kauai, which has partly bold and indented shores.

13. To give a more adequate view of the changes of level, or the evidences bearing on the subject, along the "limits" of the central area of subsidence, I mention some additional facts.

Tahiti is the large eastern island of the Tahitian Group. To the *westward*, the islands (1) decrease in size; (2) increase greatly in relative breadth of reef-grounds; (3) become deeply indented in shores, as explained; and (4) include an atoll, Tubuai, as one of the last two of the chain. While the reef of Tahiti proves little subsidence at that end of the group, and its reefs and channels are extensive enough to make the proof good, the other islands indicate, on the Darwinian theory, that the subsidence increased much in amount westward. The western end of the chain is about a degree nearer the equator than the eastern.

In the Samoan Islands, the largest island, Savaii, is the westernmost; and from there the islands decrease in size *eastward*, and end in an atoll, Rose Island. The group is like Tahiti in gradation as to increase of subsidence, but the direction is the reverse; and this fact points apparently to a much deeper area between them.* Moreover, although such broad barrier reefs as those of Raiatea and Bolabola do not occur in the Samoan group, bold shores do in Tutuila and Manua, and indicate the participation of these islands in the subsidence, notwithstanding their contracted reefs. Further, the reef of Upolu is broad enough to be proof of little change in the region of that island; and there was little, probably, at Savaii, the larger island west of it. The evidence of increased subsidence *to the eastward* is strong, and narrowness of reef is no objection to it.

At the Sandwich Islands the case is similar and yet different; similar in the fact that the largest island of the chain, Hawaii, makes one of its extremities, the eastern, and a series of coral islands the other—the whole length being 2,000 miles; but different in that *no great reef exists* about the shores of either of the eastern islands to *prove* that the subsidence there was small or none. The elevated reefs are only a local phenomenon, and do not prove the absence of subsidence during the era preceding the elevation.

But we have other evidence of importance derived from soundings about the group by the Challenger in 1875 and the Tuscarora in 1874, 1875. These soundings show that the deep-sea area of 3,000 to 4,000 fathoms comes up quite closely about the eastern end of the chain. It was found within 300 miles of

* The distance between the remote extremities of these two groups is nearly 2,000 miles, and the interval between the nearer, over 800 miles.

northeastern Hawaii and 250 of southwestern, and within 80 miles of northeastern Oahu; and a sounding but 125 fathoms less than 3,000 was obtained by the Challenger within 40 miles of eastern Hawaii (or half its diameter). To the westward, along the north side of the chain, the deep-sea area appears to be two or three times more distant, according to the Challenger results; the condition on the south side is uncertain. It would seem from the great depth near Hawaii, that the region of this great island, although it is now actively *volcanic* and *has little growing coral* about it, had undergone more subsidence than the coral reef end of the chain, and that its height and steepness of submarine slopes are due to the fact that its outflows of lava have kept ahead of the subsidence, and also built up nearly 14,000 feet above the sea.

This height is large, but the mean pitch of the sides of the volcanic mountains of the island is between 5° and 7° 45′, and hence it is only the height which successive outflows should have produced over a vent at the sea-level; and it may be that the accumulation above tide level has been made since the supposed subsidence ceased. The depth of 2,875 fathoms found by the Challenger 40 miles east of Hawaii shows a mean submarine slope to that point of 4° 30′, as if here also was a slope made by flowing lava. But more soundings are needed to prove that the slope is a gradual one.

14. The facts reviewed show *the uncertainty of evidence* as to little or no subsidence, or as to recent elevation, from (1) narrow reefs, or from (2) the volcanic character of islands, and leave untouched the evidence of actual subsidence from the features of barrier and atoll reefs and from deeply indented coasts.

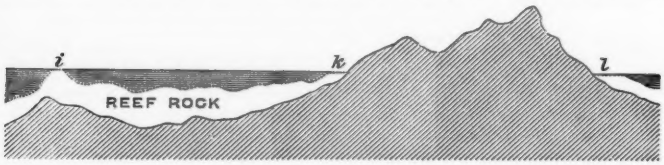
15. After the above considerations, it is clear that the theory of subsidence meets well the facts as to the varying extent of reef among reef-bordered high islands. According to it, (1) steepness of submarine slope may characterize the side of a barrier reef (as well as of an atoll) fronting east or west, north or south, as is true of high islands; but it is least likely to occur in the direction of the trend of the island or group, or that of current drift. (2) Fringing reefs, or no reefs, may characterize one side, that of bold bluffs, and wide barriers the opposite. (3) The barrier reef may be made on the submarine slopes of the land, or on a broad plateau or low-land area between ranges of elevations, one or both of which have disappeared in the subsidence. (4) By continued subsidence, the side having a fringing reef or no reef, may, later in the subsidence, be that of a very broad barrier reef, because of the form of the surface of the subsiding land; and *vice versa*.

The third of these propositions is well illustrated by the facts from the Maldives, as reported by Darwin. On account of its importance I add an illustration from the Feejees.

The great reef-grounds along the northwest sides of the two large Feejee islands, Vanua Lebu and Viti Lebu, do not indicate a subsidence proportional to their width.

Each of these islands is over ninety miles long, and together the trend is northeastward.* The northwestern reef-grounds are 10 to 25 miles wide; while on much of the southeast side of each island there is (according to the Wilkes Chart), only a fringing reef. The true explanation of the great width is found, not in the amount of subsidence alone, but largely in the existence there of a broad area of submerged land at relatively small depths. This inference is sustained by the fact that the outer barrier reef, after being simply a barrier reef for 125 miles with but two rocky islets in its course, becomes in the same line westward for 70 miles, a range of high narrow reef-bordered islands (called the Asaua Range), and then bends around southward through other rocky islands to meet the west end of Viti Lebu. The reef-grounds have thus a chain of islands as their boundary for a length of 100 miles, and simply a barrier reef with two rocky islets for the rest of the line (125 miles).

The following figure illustrates in a general way the above condition. It is a section across the reef-grounds, *i k*, and the



outer barrier reef *i*, with a fringing reef at *l;* and supposing it to have a rocky island at *i*, it represents a section (farther to the southwest) across the reef-grounds and the outer range of islands. The reason for the existence of only fringing reefs for much of the southeast side has not been particularly investigated.

16. Local elevations within the sinking area are not evidence against the Darwinian theory of subsidence. Local disturbances and faults, as both theory and the rocks of the continents show, are almost necessary concomitants of a slowly progressing change of level. Besides this, igneous conditions beneath a region are a common source of local displacements. Such displacements are therefore to be looked for in the tropical oceans, since the various high islands are volcanic, and the coral islands probably have a volcanic basement; and, moreover, the islands are not unfrequently shaken by earthquakes. The causes of

* A map of the Feejee group is contained in my Corals and Coral Islands, and of larger size in Wilkes's Narrative of the Expedition.

local displacements by either method would not necessarily interfere with any secular change of level in progress.

17. The shore-platform of an atoll, or the "flat" as called by Darwin, situated just above low-tide level, consists usually of the true reef rock, or the rock made by under-water consolidation; and its height is determined chiefly by the height of wave action, its general surface being produced by the chiseling effect of the inflowing waters. When found above its normal level it is probable evidence of an elevation; and on this kind of evidence the conclusion rests in several of the cases of supposed elevation which I mention in my Report. The width of the platform and its evenness of surface vary with the height of the tides. When the tides are five to six feet, the platform is narrow, more cut up by channels and less even in surface. After an elevation, if but a foot or two in amount, the surface of the platform becomes restored finally for a large part of its surface to its normal level and gentle slopes may connect the newer and older portions. But if the rise of an atoll is ten feet, great degradation takes place along the lifted edge of the reef, which may end in reducing the elevated coral barrier to a wall with numerous channels and broad spaces opening through to the lagoon, as observed by the writer (from ship-board) on the south side of Dean's Island.*

18. The differences in the *kinds of coral rocks* should be understood (as the recent discussions of Darwin's theory have shown) in order to appreciate the structural facts that bear on changes of level. The *beach-made* rock is of *above-water* consolidation, (through calcareous deposition about the grains as evaporation takes place), and is porous, often oölitic; and if a conglomerate it consists mostly of worn masses. The rock made of drifted sands is similar. But the true *coral-reef* rock is of *under-water* consolidation, and is usually very compact, like an ordinary limestone; and if a conglomerate it is commonly a

* Our cruise took us from the Paumotu atolls to Australia, and there, the sandstone bluffs making the capes of Port Jackson gave me my first understanding of the atoll's "shore platform." This bluff had its "shore platform," 50 to 150 yards wide, bare at low tide; it was the lower layer of the sandstone, a regularly jointed rock, lying like a loosely laid pavement. It seemed strange that it was able to keep its place in the face of the breakers. But the first waters of the incoming tide swelled quietly over it and served to shield it from the plunging waters of the later part of the flow; the waves, therefore, found nothing to batter against short of the base of the bluff.

A view of Dean's Island from the south is given in Wilkes's Narrative, i, 342; it fails only in not giving a nearly even top line to the columns. The view on p. 334 looks as if representing another example of similar erosion. But, as the text implies, the group of masses of coral rock was made by the artist by bringing into a single view the blocks that had been observed in an isolated way over the platforms of atolls. The size and shapes of the blocks are exaggerated. But, although isolated, such blocks are often so united to the coral platform that they appear to be a constituent part of it (my Report, p. 61), and suggest the question whether they may not be remnants of an overlying layer elsewhere removed.

breccia, and sometimes a very coarse breccia. Some masses of it lying on the shore-platform of Paumotu atolls (thrown up by storm or earthquake waves) 100 to 2000 cubic feet in contents, consisted of single pieces of massive corals—*Astræas, Porites,* etc.; and others were an agglomeration of fragments of corals. The fine-grained or impalpable kind made from coral mud may have few or no fossils, and be a magnesian limestone.

Another variety of the coral-reef rock, made in lagoons and sheltered channels, has the corals in the position of growth, and when formed of branching corals the spaces among the branches are often but partly filled. It is a weak rock; and the islets thus made in lagoons and inner channels are sometimes overturned by the heaviest of waves; and rising banks (as the experience of the Wilkes Expedition proves) may be crushed beneath the keel of a passing vessel.

Owing to the different modes of origin of the beach-made rock and the true coral-reef rock, the occurrence of the former underneath the latter would be evidence of subsidence.

Deep borings in atolls with circular drills that would give a six-inch core would supply evidence as to the existence or not of beach-made coral rocks at levels below the surface. They would also determine the depth to which true modern coral-reef rock extends and the nature of the underlying beds, whether calcareous, volcanic, or of any other kind; this is hence a sure method for obtaining a final decision of the coral island question and should be tried.*

19. *Elevated* coral reefs afford an opportunity to search for

*The Wilkes Expedition carried out apparatus for boring. It was put into inexperienced hands, as Commodore Wilkes states in his Narrative (iv, 267, 268), and at a trial with it on Aratica (Carlshoff Island) in the Paumotus, it became broken and useless at a depth of 21 feet. Moreover, the granulated material brought up afforded no satisfactory evidence as to the kind of coral rock encountered. The statement in the Narrative that "the low coral islands, as far as they have been investigated, both by boring and sounding, have shown a foundation of sand, or what becomes so on being broken up," has been quoted and made more of than the facts warrant. The "soundings" reached only the sands of the sea-bottom; and the "boring," if it found sand at bottom, proved only that the beach-made rock may exist at the 21-foot level, in which case a small subsidence would be indicated.

Commodore Wilkes says on page 269 of the same volume: "The elevated coral islands which we have examined exhibit a formation of conglomerate composed of compact coral and dead shells, interspersed with various kinds of corals, which have evidently *been deposited after life has become extinct.* A particular instance of this was seen at the island of Metia, and the same formation was also observed at Oahu." As the corals of a conglomerate, whether consisting of rounded masses or angular, are "deposited after life has become extinct," no inference as to the particular kind of coral rock intended can be drawn from the remark. From my knowledge of the island I presume he meant the ordinary breccia conglomerate of the reef rock, which is one of the kinds of coral rock of the elevated island. Commodore Wilkes himself made no examination of the rock or special study of coral islands, as might be inferred from his theoretical views on p. 270 of volume iv. His Narrative was to a considerable extent made up from the Journals of his various officers.

layers of beach-made rock underlying true reef rock; and also, if over 120 feet in height, to ascertain directly the character of the rock below this level.

The elevated atoll, Metia, seventy-five miles northeast of Tahiti, whose maximum height (according to the measurement of officers of the Wilkes Expedition) is 250 feet, I have described as consisting of the true coral-reef rock. My examinations were made on the west side where it presents a nearly vertical front to the water. The white compact limestone was, in some parts, almost destitute of fossils, or had only an occasional mould of a shell or fragment of coral;* and in others, it was a fine or coarse coral breccia. My notes written out at the island include the statement that "large masses of corals make some lower layers." This observation, though not as complete as I now see that it should have been, favors the conclusion that the thickness of the reef rock is at least twice as great as the depth to which reef-corals grow, in which case the elevated reef is proof of a subsidence of 120 feet or more.

The island is so near the route to Tahiti that the doubt which remains could be readily removed.

20. The subsidence indicated, according to the Darwinian theory, by atolls and barrier reefs was *actual*, not apparent subsidence attributable to change of water-level. The difference in its amount between the Central-Pacific area of subsidence and its limits (§§ 10, 11, above), the gradation or variation in amount of subsidence along chains of islands (§§ 10, 12, 13), and the local character of elevations, like those of Metia, Mangaia and many others, are proofs on this point.

The preceding explanations have prepared the way for the consideration of the arguments urged against the Darwinian theory, to which I now pass.

[To be continued.]

Art. XIII.—*On the Meteorite of Fomatlán, Jalisco, Mexico;* by Charles Upham Shepard.

For my knowledge of the Formatlán meteorite I am indebted to Mr. Carlos F. De Landero, Engineer, of Guadalajara, Mexico. Along with a fragment weighing 142 grams came his letter of March 11th, stating that it formed portion of a

*It was this compact rock, white, flint-like in fracture, clinking under the hammer, that was found on analysis by B. Silliman to contain 38·07 per cent of magnesium carbonate.

stone that fell "about the end of the year 1883 on the farm of El Garganitello, near the coast in the State of Jalisco."

The fragment is somewhat prismatic in shape, two and a half inches long and one and a half in each of its two other dimensions. The broadest side retains the original black crust, which is rough and dull, with a thickness rather above the average in meteoric stones. It is broken with medium facility, showing a rather lighter color than common in these bodies. It abounds in pisiform grains of a pearl-gray or brownish color, varying in size from a pea downward to that of mustard-seed. The larger of these may be described as not strictly pisiform, but rather flattened globules or imperfect crystals, with rounded edges and angles. They often exhibit a single tolerably distinct cleavage in one direction, with traces of another perpendicular thereto.

The basis in which the globules are imbedded is rather peculiar. It is many shades lighter in color than the globules, and is fine granular resembling certain massive albites. Under the lens it appears an intimate mixture of the broken gray globules and a white mineral. This last in the field of the compound microscope is seen to consist of sharply crystalline, transparent or semi-transparent grains, and closely resembles the chladnite of the Bishopville meteorite. It should be mentioned that the pisiform globules situated within half an inch of the crust are much stained with iron-rust.

But the striking peculiarity of the Jalisco stone is the prevalence everywhere of octahedral crystals of nickeliferous iron. These are so distinct as to be recognizable with the naked eye, the brilliant equilateral triangular faces coming into view by every change of position in the specimen. Now and then a surface presents a pitted or dissected appearance, similar to what is common in quartz crystals. One or two instances were noted where a tendency to the arborescent structure showed itself, the octahedra being aggregated in a common line, and only touching by the tips of their pyramids. Neither the irregular globular form or the twisted pisiform shape of this substance, sometimes visible in meteoric stones, is recognizable in the present case.

This observation at first led me to suppose that the Jalisco stone offered the first instance of well defined crystals of nickeliferous iron. But on recurring to the stones of several other localities, I find their presence is by no means rare, though they have not hitherto attracted attention. The following of those showing occasional crystals may be instanced: Rochester, Sumner County, Little Piney, Richmond, Yorkshire, Montrejean, Daniel's Kuill, New Concord, Vouillé, Erxleben and Affianello.

The crystals are uniformly distributed, penetrating even to the center of the chrysolite globules, and are often so minute as to be invisible without the aid of a glass. To effect their entire separation by the magnet is wholly impossible. Neither can their estimation be accomplished by the aid of acids, since the chrysolite is more or less decomposed by the same action that dissolves the crystals. The nearest approximation to their percentage, as determined mechanically, gave it at about 7 p. c., though this is probably too high, through the adhesion of the pulverized chrysolite in the process of separation.

Particles of crystalline troilite of considerable size adhere occasionally to the nickeliferous iron, though on an average they cannot exceed 0·5 p. c. of the stone. The treatment of the metallic portion of the stone in aqua regia left undissolved a few very minute black shining scales of a plumbaginous nature, together with equally minute non-magnetic, dull, octahedral crystals of chromite, which gave with borax the characteristic chromium reaction.

Equally difficult, as in the case of the nickeliferous iron, is the determination of the proportions of the chrysolite and the supposed chladnite. The nearest estimate I can make would be eight of the former to one of the latter, thus presenting the following approximative table for the mineralogical constitution of the meteorite:

Chrysolite	80
Chladnite?	10
Nickeliferous iron	7
Troilite, Chromite, Peroxide of iron	3
	100

The specific gravity as determined upon two fragments, each having about one-third of its surface covered by crust, was 3·47–3·48.

In conclusion, it may be observed that the shape of the specimen indicated it to have belonged to a stone several inches in diameter. Additional particulars relating to the fall will probably be furnished hereafter, through inquiries promised by Mr. Landero.

Charleston, April 18, 1885.

Addendum.

The delay which has occurred in the publication of the foregoing enables me to append thereto the very interesting extract from a letter of Mr. De Landero, dated Guadalajara, May 30th, 1885:

"Respecting the exact date of the fall, I shall sooner or later be able to fix it with precision. The aerolite passed over the

town of Fomatlán (40 miles S.S.E. of Cape Corrientes, a village of 800 inhabitants, belonging to the canton of Maseota in our state of Jalisco, at a height of some three to five thousand feet, between four and five P. M. It was a very clear day. Many persons saw the aerolite, and heard the explosion it made, which was very powerful. Its direction was from S.E. to N.W. It left a white cloud in its track. Two or three fragments fell, eight miles N.W. of Fomatlán, between the houses of the Gargantillo farm. The latitude of Fomatlán is 19° 44′ N. and its longitude near 6° 20′ W. of the city of Mexico. Its elevation above the sea is about 100 feet.

"The administrator of the Gargantillo farm, Cesareo Rodriguez, gathered two or three fragments of the meteorite a few minutes after their fall, when they were still at a burning heat. The largest of these weighed about two pounds. The main body of the meteorite, which must have been very large, continued on its path to the N.W. and fell into a large lagoon four or five miles distant from the farm.

"My uncle, Mr. Joaquin Castanos, who was at that time in Fomatlán, received one of the fragments from the hands of Cesareo Rodriguez, and kept it for me. I made a determination of the specific gravity of the meteorite upon a fragment weighing 28½ grams, the result of which was 3·49."

A late letter gives August, 1879, as the time of fall.

ART. XIV.—*On the widespread occurrence of allanite as an accessory constituent of many rocks*; by JOSEPH P. IDDINGS and WHITMAN CROSS, of the U. S. Geological Survey.

MORE than a year ago, while engaged in the microscopical study of rocks from widely separated regions, the writers observed in the thin sections occasional crystals or grains of a highly refracting, brown mineral, which was not referable to any of the more common rock-building species. The study of a number of sections showed that the crystals were monoclinic and apparently isomorphous with epidote, that is, elongated in the direction of the ortho-axis with the base and orthopinacoid well developed, two positive orthodomes less prominently, and with terminal planes belonging apparently to the unit prism. In a few instances imperfect cleavage was noticed parallel to $i\text{-}\bar{1}$ and O, and in one case to $i\text{-}1$. A twinning parallel to $i\text{-}\bar{1}$, as in epidote, was frequently observed.

The optical axes were found to lie in the plane of symmetry, one of the bisectrices making an angle of 35° to 40° with the vertical axis and 25° to 30° with the clino-axis. A strong pleochroism, from light yellowish brown to dark chestnut brown

was always noted, as also a high index of refraction. These characters strongly indicated the identity of this mineral with allanite, and a qualitative chemical analysis, made by Dr. W. F. Hillebrand in the Denver laboratory of the U. S. Geological Survey, fully confirmed the correctness of the microscopical determination. The material analyzed was derived from a biotite porphyrite of the Ten Mile District, Colorado, in which the mineral occurred in exceptional abundance. The process of separation and analysis is described by Dr. Hillebrand as follows: "The mineral supposed to be allanite was separated from the rock, together with much magnetite and some zircon, by means of the Sonstadt solution. The magnetite being removed by a magnet, the other minerals were left quite free from further admixture. They formed approximately 0·05 per cent of the whole rock.

"In order to preserve the zircon crystals intact, the mixture was treated, without pulverization, for many days in a platinum crucible with hydrochloric acid. The residue was zircon and silica retaining the original form of the allanite fragments. This silica after filtration was entirely soluble in hot sodium carbonate. After separating silica in the hydrochloric acid solution, the latter was boiled with potassium hydrate. The filtrate then showed much alumina and lime, and very little magnesia. The precipitate by potassium hydrate was dissolved in hydrochloric acid, diluted, and to it a concentrated solution of oxalic acid added. The precipitate, at first curdy, was ignited, dissolved in sulphuric acid, evaporated, and ignited gently, the sulphates dissolved in cold water, and crystals of potassium sulphate added. After washing the insoluble double sulphate formed with a potassium sulphate solution, ammonia formed no precipitate in the filtrate, showing the absence of erbium and yttrium. The double sulphates dissolved very readily in water acidulated with hydrochloric acid, and were then decomposed by oxalic acid; the ignited precipitate was brown, readily soluble in hydrochloric acid with evolution of chlorine, indicating thereby the presence of both cerium and lanthanum, and absence of thorium. No didymium absorption lines were visible in the spectroscope. The oxalates, when dissolved in strong nitric acid and boiled with lead dioxide, gave a yellow solution showing the presence of cerium. Further tests were rendered impossible by the loss of the material.

"Although in the beginning only a qualitative analysis was contemplated, owing to the small amount of material, nevertheless the silica, alumina, ferric oxide, mixed cerium and lanthanum oxides, and the lime were weighed, and found to bear to one another the avarage ratio of those constituents in allanite."

Considering the identity of the mineral as established, the

following additional particulars as to its characteristics and distribution may be of interest.

Crystals which are large enough to be seen without the aid of a lens are easily recognized in the hand specimen by their brilliant black color, uneven fracture and oily luster. They vary greatly in form and size in the different rocks examined, in some cases being long, slender prisms, reaching a maximum length of 1 cm., though usually appearing in short, stout prisms, or in quite irregular grains of microscopic dimensions. In thin sections from a great number of localities the color is uniformly a rich chestnut brown with the strong pleochroism already mentioned, but in a few instances a zonal variation has been noticed, the color growing lighter from the center of the crystal outward. Cleavage is in most cases wholly absent.

A confusion with hornblende or biotite is only possible when these minerals are of nearly the same shade of brown, and are so cut by the section as to show no distinct cleavage. But the lack of pleochroism and the nearly uniaxial character of a basal section of biotite—the only one not exhibiting cleavage—sufficiently distinguishes it from the strongly pleochroic, biaxial allanite. In the exceedingly rare cases where hornblende possesses the peculiar chestnut-brown color, and shows neither characteristic cleavage nor outline, one can only distinguish the allanite by its higher index of refraction, which produces more brilliant interference colors between crossed nicols.

From its mode of occurrence and association allanite must be added to the group of primary, accessory rock constituents, similar to zircon, sphene, and apatite, though much rarer than any of these. In one instance it was noticed enclosing zircon, in others, sphene, apatite, and magnetite, but it has also been found in such connection with these minerals as to indicate a contemporaneous growth. Its nature as a primary constituent in eruptive rocks is further attested by its occasional inclusion in biotite, feldspar, and quartz.

In some regions it appears to be quite uniformly distributed through certain types of rock. Thus, in the porphyrites and allied porphyries of the Ten Mile district, Colorado, prismatic crystals of allanite may be seen in numbers upon nearly every hand specimen—one exhibiting as many as forty on its surface—and few thin sections of these rocks were examined without one or more being discovered. On the other hand, in the vicinity of Eureka, Nevada, it seems to be very irregularly disseminated through a considerable range of rock types, two or three microscopical individuals being recognized in quite a number of thin sections—and in one instance as many as eleven—but in the majority of sections it is absent altogether. In most of the rocks studied the mineral occurs very sparingly.

In almost every instance the allanite is perfectly fresh and unaltered. Macroscopic crystals are occasionally seen to be reddish brown in color, with a more or less deeply stained zone surrounding them. In one partially decomposed rock, a transition of allanite to epidote is indicated by crystals of the former enclosing scattered grains of epidote in such a manner as to leave little doubt that they result from an alteration of the enclosing mineral.

It is interesting finally to notice how extensively allanite is disseminated in minute quantities through rocks of a great variety of types and from widely separated localities. Without undertaking any special investigation of the matter we have found it microscopically in metamorphic rocks, in older crystalline eruptive masses and in glassy lavas; in hornblende gneiss and mica gneiss, in granite, granite porphyry, quartz porphyry, diorite, porphyrite, andesite (glassy), dacite, and rhyolite; and from localities in the States of Maine, Massachusetts, Rhode Island, Colorado and Nevada, and the Territories of Wyoming and Utah. Below is appended a list of the rocks and localities alluded to, which will no doubt be greatly enlarged by other observers.

Gneiss.—Utah: Ogden Cañon; Farmington Cañon, Wahsatch.
Wyoming: Medicine Bow Range.
Nevada: Clover Cañon, E. Humboldt Mountains.

Granite.—Maine: Vinalhaven, Biddeford, Wayne, Fox Island, Harrington.
Massachusetts: Lynnfield.
Rhode Island: Westerly.
Utah: Little Cottonwood Cañon.
Nevada: Eureka.

Granite porphyry.—Utah: Tooele.
Nevada: Eureka.

Quartz porphyry.—Colorado: Mosquito Range, Park County; Eagle River, Eagle County.

Diorite.—Nevada: Truckee Cañon.

Porphyrite.—Colorado: Mount Silverheels, Park County; Mosquito gulch, Park County; Ten Mile District, Summit County.
Utah: Henry Mountains.

Andesite (glassy).—Nevada: Eureka.

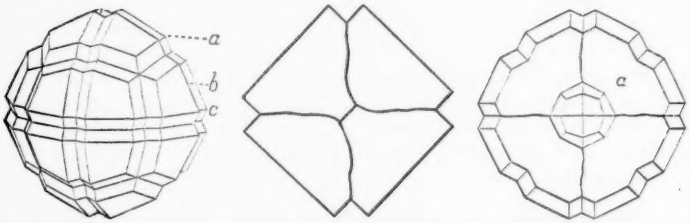
Dacite.—Nevada: Eureka, Shoshone Park; Washoe.
Utah: White Rock Mountain.

Rhyolite.—Nevada: Eureka.

ART. XV.—*Crystals of Analcite from the Phœnix Mine, Lake Superior Copper Region*; by SAMUEL L. PENFIELD.

THESE crystals which have lately been received at New Haven, occur thickly grouped together on calcite and native copper, associated with tabular crystals of apophyllite, and numerous minute crystals of milky quartz scattered thickly over the specimens. The crystals are of all sizes from very minute up to one centimeter in diameter; the small ones are simply tetragonal-trisoctahedrons of the form (211), 2-2, the larger ones are of the same form but with the planes arranged as in fig. 1. Along every edge of what might be regarded as a simple crystal, there is a reëntrant angle or groove. The crystals are mostly of ideal symmetry of arrangement, and appear as if made up of twenty-four simple crystals, each equally spaced from the center. Occasionally at the extremity of the principal axes, a fifth solid angle can be seen symmetrically situated midway between the four represented in the figure. The planes of the crystals are uneven, as is so often the case with analcite, so that it was impossible to prove by means of the reflection goniometer that the individual parts of the crystal were arranged in exactly parallel position.

1. 2. 3.



In order to obtain some insight into the interior arrangement of the crystals, some sections were cut and examined with the microscope. A cross section parallel to (001), *i-i*, at the point *a*, fig. 1, is given in fig. 2. The section is plainly divided into four parts corresponding to the four crystals, so to speak, which are intersected at that point, the division lines running nearly parallel to the diagonals of the rectangle. The figure shows the irregular direction of these dividing lines in one of the sections. at times they run much more regularly. They were observed in all cases, and can be seen with the naked eye as soon as the top of the crystal is cut away. After grinding the sections thin it is impossible to transfer the same to an object-glass without the four parts separating along these division lines, and this

is the case even when the sections are quite thick for microscopic purposes, so that in reality there are four separate individuals cut through at that point. Under the microscope the sections show a slight double refraction, but no division into definite fields, as observed by A. Arzruni and S. Koch,* could be observed. The patches of dark and light were very unequally distributed, but the extinction was in all cases at a maximum when the principal isometric axes were parallel to the planes of the polarizer or analyzer, as observed by the above mentioned authors. A section nearer the center of the crystals showed the four lines of separation as above, but no separation parallel to the dodecahedral symmetry planes, as might be expected below the point *b*, could be observed. In addition, a rectangular patch surrounded by an opaque rim was observed in the centre of the section, being the section through a central crystal or nucleus. A thick cross section between the points *b* and *c*, fig. 1, is given in fig. 3. The outer portion *a* represents the clear transparent material of the crystal with the four division lines, while in the interior a perfect tetragonal-trisoctahedron can be seen. The material of this inner crystal is transparent, but it has an opaque, white coating, and the whole outline of the crystal can be seen as distinctly as if it were a model mounted in some transparent material. After observing this in the section, it can readily be seen that all of the larger crystals have an opaque center. The transparent exterior portion shows with crossed nicols under the microscope colored patches running in radial directions from the center, the maximum of extinction being for all of the four secants when the principal axes are parallel to the polarizer or analyzer.

The outer portion would thus seem to be a secondary growth about an older analcite crystal serving as a nucleus. Each face of the original crystal seems to have acted separately in the orientation of the secondary deposit. The three crystals or parts of the crystal in each octant seems to be parallel in molecular arrangement because no lines of demarcation or separation between them can be detected, while the material of the eight octants seems to be not quite parallel in arrangement, as indicated by the division lines and easy separation which were in all cases observed.

Mineralogical Laboratory, Sheffield Scientific School, May 12th, 1885.

* Zeitschr. Kryst., v, 483.

Art. XVI.—*On a Differential Resistance Thermometer;* by T. C. Mendenhall.

The determination or registration of the temperature at a distant or not easily accessible point, is so extremely desirable that many methods for accomplishing this end have been proposed, and to some extent made use of during the past fifty years. Naturally enough electricity has been utilized in some way or other in the majority of these systems of telethermometry.

The requirements of the problem seem to be that the device or instrument used at the point, the temperature of which is to be ascertained, shall be of the greatest possible simplicity of construction involving little or no motion in its parts, so that the liability to "get out of order" shall be reduced to the minimum; and that at the observing or registering station, the necessary appliances shall possess a maximum of durability and simplicity—so that a minimum of time and skill will be demanded in making the observations. The whole system must be certain in its indications and correct within a reasonable limit.

The first of these conditions is apparently sufficiently well satisfied by the thermo-electric-junction which has probably been more extensively made use of than any other form of electric thermometer. It renders necessary, however, the use of a comparatively delicate galvanometer, and as the electromotive force of a single couple is small (it is difficult to use more than one in general practice) the results are subject to considerable errors arising from unknown or neglected sources of electromotive force. This source of error becomes more important as the range of temperature measured becomes smaller, although it may be almost entirely avoided by care and skill on the part of the operator. The well known resistance method of Siemens satisfies the same condition very perfectly, and is certainly capable of giving good results when skillfully applied, at least throughout moderate ranges.

The desire to possess some form of electric-thermometer which might be utilized in the study of certain problems connected with meteorology, especially the observation of soil and earth temperature, and the use of which would not demand greater skill than that of the ordinary meteorological observer, led to the device and construction of the instrument to be described which may be called a "differential resistance thermometer." It consists essentially of a mercurial thermometer, not unlike ordinary forms, except that the bulb is greatly enlarged so that the stem may have a diameter of something like

a millimeter, and still leave the scale tolerably "open." In one of the instruments already made 1° C. corresponds to about 5^{mm} of the scale. Running down through the stem is a fine platinum wire about $\cdot 08^{mm}$ in diameter. The lower end may be secured in the bulb so that it is kept straight in the bore of the stem, and at the lower end a heavier wire is sealed in the glass so that metallic contact can be made with this wire both at the upper end and through the mercury at the lower. It is evident that the resistance between these two points will depend largely (but not entirely) on the length of the platinum wire which is above the mercury in the tube and this will depend on the temperature to which it is exposed. When this temperature rises the resistance is decreased by an amount equal to the difference between that of the platinum wire which disappears and that of the mercury which takes its place—less the increase in the resistance of the wire and mercury due to increase of temperature.

Let l = length of platinum wire exposed at 0°.
s = resistance per unit length (= length of 1°) of wire.
g = resistance per unit length (= length of 1°) of mercury.
k = temperature coefficient of platinum.
h = temperature coefficient of mercury.
R_o = total resistance at 0°.
R_t = resistance (including all) at t^0.

Then

$$R_t = R_o - \{s(1-kl) - g\}t - (ks - gh)t^2. \qquad (1)$$

This equation is not quite rigorous, but the approximation is very close. It is of the form—

$$R_t = R_o - Bt - Ct^2. \qquad (2)$$

The simplest and best way of dealing with it is to determine the constants of the equation (2) by a series of observations making use of the method of least squares. From the result the resistance for any degree of temperature may be calculated, or better, a curve can be constructed from which the temperature corresponding to any resistance can easily be read.

The advantage of this method over the use of a simple resistance coil is that the change in resistance accompanying a given change in temperature, is much greater and in fact it may be made as great as one desires. As a result the telephone may be substituted for the galvanometer in the resistance measurements, thus greatly simplifying the apparatus as well as increasing the rapidity with which observations may be made; or if preferred, a much less sensitive galvanometer may be used. It also possesses the very great advantage of allowing an increase of delicacy as the range of temperature decreases. For earth temperatures this is very desirable and it will easily be seen that

thermometers of this kind can be constructed for a few degrees of range with which, by comparatively rude processes the measurements may be correct within a very small fraction of a degree. For use in earth temperature measurements, the thermometer will be inclosed in a strong brass tube for protection and the connection with the point of observation made by means of a cable of heavy copper wire. The cable will of course form a part of R_0 in equation (2), but as it is a constant, the substitution of one cable for another, if necessary, will affect the position and not the form of the calibration curve. Its resistance must be small, relatively, and the influence of temperature upon it may be neglected.

With this device a temperature observation may be taken in less than a minute, no time being consumed in the preparation of liquids of known temperature at the observing station as in the use of the thermo-junction or the resistance coil.

ART. XVII.—*Impact Friction and Faulting;* by GEORGE F. BECKER.

Bearing of the subject.—Some time since I submitted certain phenomena of faulting to analysis and endeavored to show how it might happen that a movement in the earth's crust, instead of being confined to a single surface, would be distributed over a great number of substantially parallel surfaces.* That such occurrences are frequent is certain. They are called step faults by Mr. Geikie† and are stated to be common in the coal fields bordering on the Forth. Professor Heim has also called attention to similar instances.‡ The parallel systems of veins found in a large proportion of mining districts, and even some forms of complex lodes, involve such a division of the country. Landslides frequently show a separation of the moving soil into extraordinarily regular sheets a foot or two in thickness, indeed during the spring of the past year I examined scores of such slides in the Coast Ranges of California, some of them covering forty or fifty acres in extent. Finally some monoclinal faults may probably be considered as step faults where the intervening masses are not too broad to permit of their displaying independent rigidity and, for these instances at least, the relations between monoclinal and anticlinal faults may be elucidated. It is clear that the subject is one of more than merely local importance and deserving of the attention both of

* The Geology of the Comstock Lode (Monograph U. S. Geol. Survey, vol. iii) p. 156.

† Text-book of Geology, p. 532. ‡ Mechanismus der Gebirgsbildung.

those interested from a scientific point of view in structural geology, and of those who desire to take advantage of such assistance as theory affords for economical purposes.

Plan of discussion.—While the extremely simple argument as to the distribution of energy in a system of material sheets in contact with one another and of the resulting geometrical effects, which was offered in the paper on faulting referred to, seems to me rigidly correct, the fact that friction plays a leading part in the problem lends it a somewhat unfamiliar character. It appears desirable, therefore, to subject friction itself to a closer examination and to show that a study of the character of this force leads to results embracing those formerly reached. Much of the material which will be presented in the following pages was prepared for my former discussion, but was omitted as not sufficiently germane to the subject of the report in which it was included. I shall first make an attempt to elucidate the distribution of energy in a rod, or any other system in which the centers of inertia of the members are arranged in the line of force, when subjected to an impact; next, to show that the results are immediately applicable to frictional problems, and then that the same results may be reached independently of any hypothesis as to the nature of a frictional surface. Finally, these results will be applied to a characterization of friction and their application to problems of structural geology will be indicated.

System of inelastic balls.—Suppose a series of inelastic bodies of equal mass, arranged in a straight line, at rest and unconstrained. If the first of these masses is started at a velocity v in the direction of its next neighbor, it will strike it, a loss of energy will ensue, the two will move off together and impinge upon the third, and so on. The loss of energy at each impact can be extremely easily calculated from the principle of the stability of the center of inertia of a system upon which no external forces act. If M is the mass of the moving body, the loss of energy when the first x bodies having coalesced and moving as one mass strike the $(x+1)$ body is say*

$$W=\frac{Mv^2}{2}\,\frac{1}{x(x+1)},$$

the equation of a locus belonging to the class of hyperbolic

* The momentum of the moving mass is constant. If therefore v_x is the velocity with which x masses move after they have coalesced

$$Mxv_x=Mv,$$

and therefore

$$v=xv_x=(x+n)v_{x+n}.$$

The kinetic energy of the moving mass before the x bodies strike the next is $\frac{Mv^2}{2x}$, and after they strike it $\frac{Mv^2}{2(x+1)}$, and the difference of these quantities is W, the energy expended.

curves. It is clear that W does not become zero until $x = \infty$, and consequently the energy is distributed over an infinite series of masses. The equation accounts for the entire energy and no more for

$$\sum_{1}^{\infty} \frac{1}{x(x+1)} = 1.$$

This equation does not accurately represent the distribution of energy in the system; for when x bodies strike the next in the series, although most of the energy will be expended at the contact, a portion will be propagated backward, and work will be done at previous contacts as well. On the other hand, it demonstrates that the distribution of energy in such a system may be discussed entirely apart from the effects which the energy exerted at any point produces upon the material of the system. If the masses of the members of the system remain constant, their density may vary regularly or irregularly without affecting the above equation. If two or more of the equal members of the system were joined together before impact, this would not in any way affect the distribution of energy, so that the equation holds good for bodies of which the mass varies regularly or irregularly, provided that x varies as the mass.

Distribution of energy in finite masses.—The transmission of energy in solids or liquids is not instantaneous. It follows that if two elastic bodies of the same material, but of unequal length, meet one another, a portion of the energy is converted into vibration. This is not the case with inelastic bodies, which remain permanently in the condition of maximum deformation. The transmission of energy however is extremely rapid, and Messrs. Thomson and Tait estimate that the entire impact of two balls a yard in diameter of copper, glass or steel, occupies a period within the thousandth part of a second. I shall consider the transmission instantaneous. On this supposition the centers of inertia of equal masses of a form varying from that of a cylinder will behave like the centers of inertia of such cylinders, and the distribution of energy among the centers of inertia in a rectilinear series of balls (for example) become reducible to that in a cylinder of invariable cross section but compressible in the direction of its axis. The distribution of energy in a perfectly elastic mass of constant temperature at the moment of maximum compression is also that which would be produced by the action of a constant force of appropriate intensity on the same body. It represents too the permanent effect of an impact upon a perfectly inelastic mass, so that the solution of one of these cases is the solution of all three.

From the instant at which an impinging mass first comes in contact with a passive mass, to the moment at which the centers of inertia come to rest relatively to the center of inertia of the system, the active and reactionary forces are in equilibrium. This is manifestly the case for elastic bodies, and since during this period elastic and inelastic bodies behave exactly alike, inelastic bodies are reducible to a conservative system for the same period. The principle of virtual velocities is therefore continuously applicable and the energy potentialized (or expended) in the two masses is equal in absolute value and opposite in direction. The kinetic energy at the moment of maximum compression on the other hand will be uniformly distributed (relatively to the mass) over the entire system.

Solution for finite compressible rod.—The geometrical methods of representing energy are as various as the corresponding algebraic notations, but perhaps the most natural is that in which the energy of a moving body is made proportional to the volume of the body and to its energy per unit of volume. If the energy potentialized throughout a given volume were uniformly distributed, the quantity of energy potentialized in a cubic unit would then be, say w, and that in an infinitesimal cube would be $w dx\, dy\, dz$. Suppose a finite compressible cylinder at rest to suffer impact from a second similar cylinder moving with a velocity v. It will be convenient to consider the mass of the moving cylinder as $2M$ and that of the passive cylinder as $2nM$. The entire energy potentialized in the passive mass at the moment of maximum compression will then be $\frac{Mv^2}{2}\frac{n}{n+1}$, and the kinetic energy of the whole system at the same instant will be $\frac{2Mv^2}{2}\frac{1}{n+1}$. The problem proposed is to find an expression for the distribution of potentialized energy throughout the passive mass, or to state w in terms of x, for the moment of maximum compression.

Between any two successive sections w will be diminished by two quantities, one representing the kinetic energy imparted to the mass between these sections, and the other the energy potentialized. Indeed these quantities may be thought of separately as if a certain amount of kinetic energy were first distributed uniformly over the passive mass and afterward a certain quantity of internal work were done in it. If the length of the entire system is unity, the diminution of w betwen x and $x+dx$ due to the uniform distribution of kinetic energy will be $\frac{2Mv^2}{2}\frac{dx}{n+1}$. The energy potentialized between these limits is of course $w dx$, but this quantity does not bear a simple relation to dw unless none of the energy assumes the kinetic

form, or in other words, unless the passive mass is infinite. Were this the case w would be diminished by and could be diminished only by wdx; and $dw=wdx$, the differential equation of the simple logarithmic curve. But when a portion of the energy imparted to the section at x reappears as kinetic energy, dw must have a greater negative value. The equation might be written $dw=-wdx-Qdx$, but here Q must be some function of w. Now it is an elementary condition of equilibrium in the case under discussion that for a given displacement at any section, say the one at x, the energy potentialized between this section and the free end of the rod shall be a minimum, so that if a is the value of x for this end of the rod

$$\int_x^a w dx = \text{min.}$$

This minimum must have its maximum value when the entire energy is potentialized or when $a=\infty$. But if $dw=-wdx$ and a (or n) is infinite

$$\int_x^a w dx = -\frac{dw}{dx},$$

so that the infinite rod being merely an extreme case of a finite one, the integral for finite a must be less than $-dw/dx$ by a value which disappears when the kinetic energy of the system at the moment of maximum compression is zero. The effect of the uniform distribution of kinetic energy upon the value of dw has already been traced and the equation

$$\int_x^a w dx = -\frac{dw}{dx} - 2\frac{Mv^2}{2}\frac{1}{n+1},$$

therefore fully accounts for both the kinetic and the potentialized energy. For $x=a$, w must disappear, and this definite integral may therefore be written $C-fwdx$. Introducing this value and differentiating

$$\frac{d^2w}{dx^2} = w.$$

If an arbitrary unit of measurement, c, is adopted in this equation and w and x are each divided by it,

$$c^2\frac{dw^2}{dx^2} = w,$$

which leads without difficulty to

$$w = A\varepsilon^{-x/c} + B\varepsilon^{+x/c},$$

where A and B are arbitrary constants to be determined both in sign and value by the conditions.

Determination of constants for general case.—For the free extremity of the passive mass $w=0$ and therefore

$$B = -A\varepsilon^{-2a/c},$$

or in general,

$$W=A(\varepsilon^{-x/c}-\varepsilon^{-2a/c}\varepsilon^{x/c}).$$

Here $\varepsilon^{-2a/c}$ is independent of A, and the latter retains the same value even when $a=\infty$, or when the passive mass is infinite. In this case of course the entire energy of the system is potentialized (or expended if the material is inelastic). If m is the mass which the unit volume would possess were it compressed to the density which the impact produces at the face of the infinite rod and if c is so chosen that $cm=M$

$$\int_0^\infty w dx=Ac=\frac{mv^2c}{2},$$

or

$$w=\frac{mv^2}{2}\varepsilon^{-x/c}.$$

It will be convenient to retain for c the signification which it assumes when the passive mass is infinite because of the simple relations which it then bears to the energy of the impinging body. The unit chosen in any case is of course entirely arbitrary, but the results are much simplified by establishing some rational relation between the units adopted for different cases. Let the product of the entire energy potentialized in any case into the corresponding unit be a constant; then if V is the energy potentialized in an infinite rod, and V_1 the energy potentialized in a finite rod, $Vc=V_1c_1$, or

$$c_1=c\frac{n+1}{n},$$

so that the equation for a finite rod may be written

$$w=A(\varepsilon^{-x/c_1}-\varepsilon^{-2a/c_1}\varepsilon^{x/c_1}).$$

Now for $n=\infty$, $c_1=c$, and therefore the value of A already found is valid for the new equation. From

$$w=\frac{mv^2}{2}(\varepsilon^{-x/c_1}-\varepsilon^{-2a/c_1}\varepsilon^{x/c_1}).$$

it follows that

$$\int_0^a w dx=\frac{mv^2c_1}{2}\left(1-\varepsilon^{-a/c_1}\right)^2=\frac{mv^2}{2}\frac{cn}{n+1}.$$

Reintroducing the value of c in terms of c_1, it will readily be seen that

$$\varepsilon^{a/c_1}=n+1,$$

a value which can also be otherwise obtained. This also gives

$$c_1(1-\varepsilon^{-a/c_1})=c.$$

The equation of the distribution of energy in a finite rod,

the contact being taken as origin, may therefore be written

$$w=\frac{mv^2}{2}\left(\varepsilon^{-x/c_1}-\frac{\varepsilon^{x/c_1}}{(n+1)^2}\right).$$

If the origin is transferred to the free extremity of the rod by substituting $x+a$ for x, this becomes

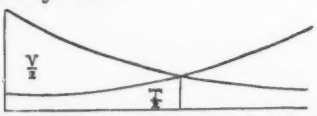
$$w=\frac{mv^2}{2}\,\frac{\varepsilon^{-x/c_1}-\varepsilon^{x/c_1}}{n+1}.$$

If $\frac{mv^2}{2}$ is taken as the unit of energy and c_1 as the unit distance,

$$w=\frac{\varepsilon^{-x}-\varepsilon^{x}}{n+1},$$

a form of very satisfactory simplicity. If $n=1$ $c_1=2c$, or the length which the entire impinging mass would assume were it uniformly compressed to the density at the contact when the passive mass is infinite.

In the following diagram the area marked $\frac{V}{2}$ is the energy potentialized in the passive mass, or half the entire energy potentialized in the system.



When the mass 2M strikes the mass $2n$M the kinetic energy of the entire system at the moment of maximum compression is, say

$$\mathrm{T}=\frac{2\mathrm{M}v^2}{2}\,\frac{1}{n+1}=\frac{2mv^2}{2}c\varepsilon^{-a/c_1}=\frac{2mv^2}{2}c_1\varepsilon^{-a/c_1}\left(1-\varepsilon^{-a/c_1}\right).$$

and this is manifestly twice the integral of the area marked $\frac{\mathrm{T}}{2}$ in the diagram. If T_1 is the kinetic energy of the passive mass alone at this moment, it is readily seen that

$$\mathrm{T}c_1=\mathrm{T}_1c.$$

If V is the energy potentialized in the entire system and E the total energy, the fundamental energy equation

$$\mathrm{V}=\mathrm{E}-\mathrm{T},$$

becomes

$$2\int_{-a}^{0}w\,dx=\frac{mv^2}{n+1}\int_{-a}^{0}\varepsilon^{-x/c_1}dx-\frac{mv^2}{n+1}\int_{-a}^{0}\varepsilon^{x/c_1}dx.$$

$$=\frac{mv^2}{n+1}c_1\left(\varepsilon^{a/c_1}-1\right)-\frac{mv^2}{n+1}c_1\left(1-\varepsilon^{-a/c_1}\right)$$

$$=2\frac{\mathrm{M}v^2}{2}-2\frac{\mathrm{M}v^2}{2}\,\frac{1}{n+1}.$$

Case of the atmosphere.—A peculiar case arising under the general equation is that in which the passive body, though of finite mass is of infinite volume, and therefore, in its uncompressed state, of infinite tenuity. Here the value of a being infinite, the coefficient B disappears and the equation assumes the simple logarithmic form. The value of the energy at the contact, however, cannot be affected by the fact that there is no limit to the expansion of the material. A therefore assumes the value

$$A=\frac{mv^2}{2}\left(1-\frac{1}{(n+1)^2}\right)=\frac{m_2v^2}{2},$$

and the base of the equation diminishes in such proportion as to give the correct integral. If c_2 is the exponential constant for this case

$$\frac{m_2v^2}{2}c_2=\frac{mv^2}{2}\frac{cn}{n+1}$$

$$c_2=\frac{n+1}{n+2}c$$

$$w=\frac{m_2v^2}{2}\varepsilon^{-x/c_2}=\frac{mv^2}{2}\frac{n(n+2)}{(n+1)^2}\varepsilon^{\frac{-(n+2)x}{(n+1)c}}$$

For a perfect gas under the compression produced by the impact of a body of its own weight $n=1$. The value m_2 is the actual mass of the unit volume at the contact of the masses, and c_2 is one-half the length which the volume of gas would have if uniformly compressed to m_2.

The average stress, due to the elasticity of a solid, when strained from its natural condition to that of a given strain, is just half the stress required to keep it in this state of strain.* If the energy potentialized in the passive mass by an impact at the moment of maximum compression is $\frac{Mv^2}{2}$ the effect of a constant force of corresponding intensity would be to potentialize an energy $\frac{Mv_1^2}{2}$ where $v_1=\frac{v}{2}$. If a column of uncompressed gas possessing the mass of a column of the atmosphere of the same section, were to strike the earth at a velocity g, the average potentialized would be $\frac{Mg^2}{2}$. This is four times of the energy actually potentialized in the atmospheric column. In general if the energy diagram for the impact of a mass 2M moving at a velocity v and impinging upon a mass $2n$M is reduced to half its dimensions, or if it is interpreted in terms of a unit twice that used in plotting it, the result is the distribution of energy

* Thomson & Tait, Nat. Phil., § 674.

due to the action of a constant force Mv on the mass $2n$M. If p is the pressure at any point and s the strain, we have in general

$$dw=pds.$$

If the stress and strain are in a constant ratio, say k, $ds=kdp$ and

$$w=\frac{kp^2}{2}.$$

If p_0 is the value of p for the contact plane of the masses, and w_0 the value of the energy for the same surface,

$$w : w_0=p^2 : p_0^2.$$

For the atmosphere therefore

$$p=p_0\varepsilon^{-x/2c_2}$$

Here c_2, as already pointed out, is half the height which the atmosphere would have were it uniformly compressed to the density at the bottom of the column; $2c_2$ is therefore the familiar "height of the homogeneous atmosphere," and the equation is the barometric formula, introduced here merely as a check upon the reasoning.

Case of a rivet.—If the coefficient B is positive instead of negative the entire energy will be potentialized within finite limits. This is possible only when the passive mass is subjected to two impacts in opposite directions, or when it rests against an infinite mass which may be regarded as rigid. In this case one-half of the entire energy will be potentialized in the finite passive mass. The general equation shows that the energy is to be considered as imparted to the passive mass from opposite directions, and it is evident that the result is the same as it would be if the energy were first distributed over an infinite mass, and the energy potentialized beyond $x=a$ were then restored to the finite cylinder from the opposite direction. The equation may therefore at once be written for the contact as origin

$$w=\frac{mv^2}{2}\left(\varepsilon^{-x/c}+\mathrm{B}\varepsilon^{x/c}\right).$$

This curve must be horizontal at some point, say $x=a$, and if dw/dx is made equal to zero $\mathrm{B}=\varepsilon^{-2a/c}$. According to the preceding

$$\int_0^a \varepsilon^{-2a/c}\,\varepsilon^{x/c}dx=\int_a^\infty \varepsilon^{-x/c}dx.$$

which gives

$$\varepsilon^{2a/c}=\varepsilon^{a/c}(\varepsilon^{a/c}-1).$$

Now in a former paragraph it was shown that

$$\varepsilon^{a/c_1}=\varepsilon^{na/c(n+1)}=n+1.$$

and this gives an expression for $\varepsilon^{a/c}$ which makes

$$\varepsilon^{2a/c} = (n+1)^{\frac{n+1}{n}}\left((n+1)^{\frac{n+1}{n}} - 1\right).$$

If the origin is removed to the base of the ordinate of the horizontal point of the curve the equation may be written

$$w = \frac{mv^2}{2}\,\frac{\varepsilon^{-x/c}+\varepsilon^{x/c}}{\varepsilon^{a/c}} = \frac{mv^2}{2}\,\frac{\varepsilon^{-x/c}+\varepsilon^{x/c}}{\varepsilon^{a/2c}(\varepsilon^{a/c}-1)^{\frac{1}{2}}}$$

$$= \frac{mv^2}{2}\,\frac{\varepsilon^{-x/c}+\varepsilon^{x/c}}{(n+1)^{\frac{n+1}{2n}}\left((n+1)^{\frac{n+1}{n}}-1\right)^{\frac{1}{2}}}$$

the equation of a "projected catenary." If the strain is proportional to the stress, this corresponds to the form assumed by a cold rivet, and it is under this law that the head of a drill spreads in use. For $n=1$ the equation assumes the simple form

$$w = \frac{mv^2}{2}\,\frac{\varepsilon^{-x/c}+\varepsilon^{x/c}}{2\sqrt{3}}.$$

Application to incompressible masses.—The problem of the distribution of energy in a finite or infinite cylinder, compressible in the direction of its axis only and subjected to an impact or a constant force, thus appears capable of entirely satisfactory solution on the supposition that the transmission of energy is instantaneous. The conditions as to compressibility answer to those of a gas confined in a rigid cylinder and are not those of solids. But since solid masses act as though concentrated at their centers of inertia, the formulas deduced are applicable to the positions of the centers of inertia of incompressible elastic or inelastic bodies. They therefore also represent completely the distribution of energy in incompressible rods capable of lateral deformation for infinitely small strains produced by impact, and approximately for small but finite strains. For constant forces acting in parallel lines or from a center at an infinite distance, in short when the equipotential surfaces are planes, the equations appear to represent the distribution of energy even for finite strains.

The character of the divergence when the equipotentials are not planes, or for central forces, is best seen by taking the extreme case of an impact acting at a point in the center of a thin sheet of elastic or inelastic material. Here the energy will be distributed at right angles to the direction of the impact, and the mass of matter over which it is distributed instead of increasing with x will increase with πr^2. If this area is denoted by z, and if the sheet is supposed infinitely thin or of finite

thickness and infinitely little strained, the distribution of energy will be represented by

$$\frac{w}{c_1} = \frac{\varepsilon^{-z/c_1} - \varepsilon^{z/c_1}}{n+1}.$$

The resulting depression will be a figure of revolution, and if the strain and stress are simply proportional, the curve generating this figure will be of the form

$$\frac{y}{c_1} = \frac{\varepsilon^{-x/2c_1} - \varepsilon^{x/2c_1}}{n+1}.$$

This result can be at least qualitatively tested by experiment. For this purpose I clamped a thin sheet of elastic rubber to a block of wood by a metal ring, and inserted a pointed instrument from beneath the block through a vertical hole at the center of the ring. The rubber was of course strained to conoidal shape, which was more or less sharply pointed according to the pressure. It was found that the generating curves for various pressures sensibly coincided with curves plotted from the above equation for various values of n. A form of the same character must be produced when a pointed instrument is being driven through a metallic sheet, just before penetration.

It is now easy to see the general character of the deformation which takes place when two spheres strike one another. If the sphere is supposed divided into segments of equal mass by planes at right angles to the direction of the impact, and each mass is considered as concentrated at its center of inertia the energy potentialized will be distributed among these centers as in a compressible finite cylinder. The plane section however, will not remain plane but will be indented in the direction of the force. At the point opposite that at which impact takes place, the surface will remain spherical while the contact of the two spheres will be a plane. An exact analysis of this case would probably be somewhat complex.

Effect of imperfect restitution.—Certain comparisons may easily be made between the behavior of totally inelastic or totally elastic bodies as hitherto treated and actual matter which is neither absolutely elastic nor perfectly plastic. Except under conditions which cannot be realized in practice, a portion of the energy received by any one of a series of bodies from an impact is always expended in internal work. Newton found that when the impact is not violent enough to produce sensible permanent deformation, the relative velocity of impinging bodies, after impact bears a proportion to their relative velocity before impact which is constant for the same two bodies. It is well known that at least a part of the

energy not returned must be employed in producing elastic vibrations of the body struck. Messrs. Thomson and Tait therefore call the coefficient representing the relation of the velocities the coefficient of restitution instead of the coefficient of elasticity as it has commonly been designated. If this coefficient is e, the coefficient of energy potentialized is expressed by $1-e^2$. If an infinite series of bodies, say spheres, not wholly inelastic, receive an impact they will be compressed as if totally without elasticity, a portion of the energy received by each will be expended in permanent deformation and in vibration and each will recoil with less force than that with which it was compressed. Now if e is constant for the system, the same proportion of the energy received by each member of the system (viz: $1-e^2$) will be expended in it; and as the quantities of energy received stand as has been shown in a geometrical ratio, so also will the quantities of energy expended. The coefficient e is not constant for partially elastic bodies and so far as I know it has been but little studied. There is reason to suppose, however, that it varies slowly with the velocity and that it is therefore approximately the same for similar bodies within considerable ranges of velocity.

Passage to frictional sheets.—Having discussed the distribution of energy in a finite or infinite system when the centers of inertia are rectilinearly arranged in the direction of the active force and endeavored to check the results by reference to experience, I now pass to the application of these results to friction. Impinging bodies may be given any desired form under proper restrictions. Suppose for example a series of inelastic plates like the following:

let them be restricted to motion in horizontal planes and pass over one another without friction. If the first of this series is started in the direction of its neighbor and the system is left to itself, the momentum will remain constant, the energy introduced into the system will be distributed over the whole infinite series and, in short, the distribution of energy in a direction vertical to the line of motion will be exactly the same as it has been found to be for a rod in the line of force. Instead of a single lug at the extremity of a sheet an indefinite number of small teeth may be supposed to be distributed over the surfaces of the sheets, and if these teeth are very minute in size and very numerous, a frictional surface as I understand it is the result. It might for an instant seem an objection to this supposition that as such sheets pass over one another the teeth will be ground off and the frictional resistance will diminish. This fact however affords an argument in favor of the truth

of the conception, for it is well known that machines, however well finished, tend to heat until the bearings have adjusted themselves to one another. The friction cannot be indefinitely reduced by this mutual action because the dust produced by the abrasion is sufficient to cause constant fresh inequalities in the surfaces.* The character here attributed to a frictional surface is substantially that which various writers have assigned to it; some of the logical results however seem to me to have escaped attention.

[To be continued.]

ART. XVIII.—*A Standard of Light;*† by JOHN TROWBRIDGE.

THE discussions in the Paris Conference of 1881–84 upon the subject of a standard of light, which resulted in the adoption of the light emitted by a surface of platinum at the point of solidification, seemed to assort ill with the discussions which led to a reaffirmation of the value of the C. G. S. system of absolute physical units, and a recognition of the relations between work and heat, and electrical energy.

The solidification point of platinum may be a fixed point in nature; but it has not been shown how this fixed point can be connected with the great web of physical measurements which has been woven by Weber, Helmholtz, Thomson, Maxwell, and other physicists. It is true that during the discussions of the Conference reference was made to a proposition of Schwendler, that the light emitted by a strip of platinum rendered incandescent by a known electrical current should be taken as a standard. This proposition, however, received little support; and the Conference finally adopted the light emitted by solidifying platinum as a standard.

It seems highly desirable that any standard of light which may be adopted should be connected with the present system of absolute measurements. The suggestion of Schwendler, therefore, seems to merit more attention than it has received. The suggestion of employing the light from a strip of platinum rendered incandescent by an electrical current is really due to Dr. John W. Draper, of New York, who in 1847 enunciated it as follows: "A surface of platinum of standard dimensions raised to a standard temperature by a voltaic current will always emit a constant light. A strip of that metal one inch

* As I pointed out in my former paper, page 158, the friction of ideally lubricated surfaces, in which the solid surfaces do not come in contact, is a very different matter. The statement as there given has since been amply confirmed by the report of a committee of the British Association.

† Read before the American Academy of Arts and Sciences, May 26, 1885.

long and one-twentieth of an inch wide, connected with a lever by which its expansion might be measured, would yield at 2000° a light suitable for most purposes."*

It has been urged against this standard that different specimens of platinum will emit different amounts of light with the same difference of potential; and that it would be difficult to carry out a measurement of the light and the strength of the current all at the same instant. With a view to obtaining a knowledge of the practical difficulties in this measurement, I interposed a fine platinum wire between the poles of a battery, and endeavored to measure the light emitted, together with the difference of potential at the extremities of the wire and the amount of current which passed through a tangent galvanometer. The difficulties, however, in using a fine platinum wire with a moderate battery power were great. The wire would fuse before the measurements could be satisfactorily made. I then employed a strip of platinum foil 5^{mm} wide, about 5^{cm} long, and about $\cdot02^{mm}$ in thickness. This was placed in a shunt circuit of a small Gramme machine in order that if the strip should fuse the dynamo machine might not race. With the proper speed and a suitable adjustment of resistances, the light from this platinum strip could be maintained very constant.

The strip was placed in a long Ritchie photometer box, which was provided with two mirrors inclined according to the plan of Ritchie. One half of the photometer disk was illuminated by the incandescent strip, and the other half by a sperm candle.

The electrical current was measured by a tangent galvanometer of which the reduction factor was ·44 in the C. G. S. system. The difference of potential at the ends of the strip was measured by a Thomson quadrant electrometer, the deflections of which were compared with that of a Daniell cell, the electromotive force of which was approximately 1·09. A Thomson voltmeter was also used. The indications of this instrument agreed with those of the electrometer. The following table gives the deflections of the instrument:

Deflection of Tangent Galvanometer in Degrees.	Deflection of the Electrometer in Centimeters.	
63	5·3	Light the color of a candle.
61	4·9	
59	4·6	
57	4·3	
54·5	3.8	
53·75	3·4	Light very dull red.

One Daniell cell gave a deflection with the electrometer of

* Scientific Memoirs, p. 45.

1·3^{cm}. The resistance of the platinum strip when cold was ·2 of an ohm. It will be seen from the above results that the current varied approximately from 8 to 6 webers, with an electromotive force of from 3·8 to 2·6 volts, while the resistance varied from ·47 to ·44 of an ohm, the resistance when cold being ·2 of an ohm. The range of the indications of the electrical instruments was comparatively small, while the light varied enormously. It is evident that the chief difficulty of this method is in measuring a strong current with accuracy: for an increase in the current represented by a fraction of a degree of the tangent galvanometer will result in a very large increase in the light from the incandescent strip.

I next endeavored to ascertain if a thermal junction enclosed in an Edison incandescent lamp, at the center of the carbon loop, would be sensitive to changes in the heat radiation of the lamp. It is evident that, if this were the case, the carbon loop might be raised to the same point of incandescence in successive times, assuming that the thermal junction at this point of incandescence receives the same amount of radiant energy. Mr. Edison kindly provided me with a lamp in which one thermal junction of an alloy of iridium-platinum and platinum was inserted at the center of carbon loops. The other junction was placed in ice and water. The thermo-electric force of this combination, however, was extremely feeble. The difficulty of inserting wires of other metals into glass prevented me from carrying this idea further. Instead of the thermal junction a small loop of extremely fine platinum wire was placed at the center of a carbon loop in an Edison lamp. This fine wire constituted a bolometer strip and made one branch of a Wheatstone's bridge, it being my intention to place a similar strip in another branch of the bridge, thus making a bolometer. The lamp was placed in a photometer box, and its light was compared with that of a candle as it was raised from a red glow to a light of fifteen-candle power. At the same time the resistance of the fine platinum wire was measured by a Wheatstone's bridge. The following table gives the results:

Resistance of the Strip in Ohms.	Distance of Carbon Lamp from Photometer Disk.	Distance of Candle from Photometer Disk.
14·42	70^{cm}	40^{cm}
14·45	85	40
14·55	98	40
14·62	108	40

This method seems to be quite sensitive. The change in resistance is large when estimated by the number of ohms necessary to restore a balance to the bridge. It was noticed that at a certain point a comparatively small increase in heat radiations was accompanied by a large change in the amount of

light emitted. This phenomenon had been noticed early by Dr. J. W. Draper. One Leclanché cell with five ohms in the circuit beside the resistance of the strip was sufficient to raise the latter to a red heat, and precautions were then necessary to prevent a change of resistance from the heating effect of the battery employed with the Wheatstone's bridge. Being desirous of ascertaining whether the resistance of the platinum wire changed after it had been heated to a red heat and had been allowed to cool, I arranged the resistance of the battery circuit outside the bridge, so that the wire could be raised to a red heat, and then, having quickly weakened the battery circuit, remeasured the resistance of the strip. No difference could be perceived in the resistance of the strip. This illustrated the fact discovered by Professor Langley, that thin strips of metal arranged as bolometer strips give up heat very quickly.

The results of this experiment led me to think that a bolometer strip of definite surface could be placed at a fixed distance from a carbon loop of definite dimensions inside an exhausted glass vessel. The amount of radiation which the bolometer strip receives could be calculated; and we might base our standard of light upon the point of incandescence which would give a definite radiation at a fixed distance. We could not distinguish by this method the energy produced by rays of different refrangibility. It seems desirable, however, to substitute for the uncertain estimation of colored lights by the eye an instrument which will measure the energy produced by the radiating source at a certain distance. Within certain limits I found that the bolometer strip would indicate an increase or decrease of the amount of radiant energy received while the difference in color of the incandescent lamp made the observer at the photometer entirely uncertain of his measurements.

Owing to the difficulty of obtaining the proper apparatus for the prosecution of the study of this method, I then studied the question of the practicability of employing a thermopile to measure the amount of radiation from an incandescent strip of platinum at a fixed distance. Within a long photometer box was placed a thin brass vessel containing water. Steam was passed by means of a rubber hose into the water of this vessel which was thus maintained at a constant temperature of about 94° C. The outside of the vessel was about 92° C. This was ascertained by making the side of the vessel constitute one metal of a thermal junction. Between this vessel and the platinum strip, which was made incandescent by a current of from 8 to 9 webers, was placed a thermopile. The face of the thermopile was thus exposed to the radiation from a given amount of heated surface at a constant temperature, while the

other was exposed to the radiation of a given surface of platinum. The faces of the thermopile were provided with the customary cones, and a series of diaphragms of thick card-board extended between the radiating surface of the vessel containing the heated water and the platinum strip. The thermopile was connected with a short coil galvanometer, and was moved until the galvanometer needle came to zero. This arrangement was extremely sensitive—a movement of a centimeter in the position of the faces of the pile being sufficient to drive the spot of light from the galvanometer mirror off the scale, corresponding to a movement of nearly fifty centimeter scale divisions. There is no difficulty in effecting a balance as quickly as an ordinary photometric measurement is made. While one observer compares a candle or other source of light with the light from an incandescent strip of platinum, another could make the measurements with the thermopile, and could obtain the amount of energy radiated by the incandescent strip in terms of the constant source of heat. It is necessary to reverse the faces of the thermopile, or to place a second constant source of heat on the same side upon which the incandescent strip is placed. The following table indicates the character of the results:

Deflection of the Tangent Galvanometer.	Temperature of Water.	Distance of Face of Pile from Water.	Distance of Face of Pile from Strip.	Remarks.
°	° C.	cm.	cm.	
57·5	95	26·5	49·5	Dull red.
56·5	95	28·0	48	
61	96	25·5	50·5	Bright yellow.
62·5	96·5	24·5	51·5	" "
62·5	96	23·0	53	" "
60·5	97	25·7	50·3	" "
58·5	97·5	26·7	49·3	" "
60	95	24·2	51·8	" "
62·2	94	23·7	52·3	" "

The reduction factor of the galvanometer was ·44 in the C. G. S. system. When the photometric indications were the same, the thermopile indicated a large change in the amount of heat received. Thus the heat indications within the range in which the experiments were taken were far more sensitive than the photometric indications.

It seems possible, therefore, to assume as a standard of light an incandescent strip which radiates a definite amount of energy, this energy being measured at a fixed distance which will best agree numerically with the absolute system of measures now universally adopted in heat and electricity. The method of Draper and Schwendler could be combined with the methods I have described above. For a practical standard, a

carbon loop in an exhausted vessel raised to such a point of incandescence that it will radiate a definite amount of energy—this energy being measured by a bolometer strip or the thermopile at a definite distance from the carbon loop, and also being measured by the formula $JH = C^2Rt$, would have a greater range than an incandescent strip of platinum placed in free air. The latter method, however, for the incandescence which produces a light similar in color to that of a sperm candle, is extremely sensitive, and can be made, I think, more exact than present photometric tests. Both methods have the great advantage of substituting a measure of energy for a relative indication by the eye, which is not connected with any absolute measurement.

These remarks apply to the question of a standard of light for practical purposes, which shall also be scientific in so far that more refined scientific investigation can connect this standard at any time with more precise methods of measuring the exact amount of heat given by radiations of definite wavelength. By means of a Rowland concave grating and with a bolometer strip, one can at present measure the energy of definite radiations. We can say that our scientific standards for light of different colors shall be based upon the energy received upon a definite surface at definite points in the diffraction spectrum.

Jefferson Physical Laboratory, Harvard College.

ART. XIX.—*On Hanksite, a new anhydrous sulphato-carbonate of sodium, from San Bernardino County, California;** by WM. EARL HIDDEN.

IN the very complete and attractive exhibit of California minerals brought to the World's Industrial and Cotton Centennial Exposition at New Orleans, by Professor Henry G. Hanks, State Mineralogist of California, were several species of unusual interest. Among these was the new borate, colemanite, in large and brilliant crystals, much resembling the finest of the Bergen Hill datolites; also the new vanadium mica, roscoelite, mixed mechanically with much native gold between the folia; borax crystals, clear and bright, of unusual size; stibnite in fine crystals almost equalling the late discoveries in this species in Japan, and many others equally noteworthy.

Of particular interest to the writer was a small lot of apparently hexagonal crystals to which had been given the name of thenardite. Now as thenardite crystallizes in the orthorhombic system, I was prompted to question the correctness of this

* Read before the New York Academy of Sciences, May 25, 1885.

determination. The results of measurements confirmed my first suspicions of their true hexagonal character, though only approximate, being made with a hand goniometer. Since, however, the hexagonal aspect of the mineral might possibly be due to complex twinning of orthorhombic individuals, it seemed advisable to have this question decided on the basis of an optical examination. For this purpose three of the best crystals were kindly given by Professor Hanks, and these were sent by me to Dr. Edward S. Dana; the crystals being quite clear. In a few days he reported them to be normally uniaxial with negative double refraction, and thus they were positively proved to be different from thenardite. An analysis being now necessary to settle the composition of the mineral, I placed sufficient material in the hands of Mr. James B. Mackintosh, E. M., for that purpose, and he has very kindly done the work, with the following results:

		Corresponding to	
SO_3	45·89	Na_2SO_4	81·45
CO_2	5·42	Na_2CO_3	13·06
Cl	2·36	NaCl	3·89
Na_2O*	46·34	Na_2O (excess)	1·08
			99·48

These results give the following molecular ratios for

Na_2SO_4	57·3	or	3·95
Na_2CO_3	14·5		1·00
NaCl	6·65		·46
Na_2O	1·75		·12

Or closely in the ratio of $4 : 1 : \frac{1}{2} : \frac{1}{2}$. This points to the formula,

$$4(Na_2SO_4) + Na_2CO_3 + \tfrac{1}{2}(NaCl)$$

as representing the composition of the crystals under examination. Neglecting the sodium chloride as non-essential, the formula becomes:

$$4Na_2SO_4 + Na_2CO_3$$

which is probably the true one.

The observed excess of soda is either due to errors of analysis, as only a small quantity was used, or it may have been combined with boracic acid, as borax is very abundant at the locality.

The interesting anomaly of a sulphate and carbonate being in chemical combination reminds us of the rare sulphato-carbonate of lead, leadhillite, to which this alone bears relation as a natural species.

The angles obtained were as follows:

O on *I* = 90°.	*O* on 1 = 130° 30′.
I on *I* = 120°.	*O* on 2 = 113° 30′.

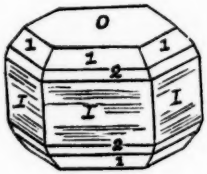
Accordingly, the value of the vertical axis is 1·014. Cleavage parallel to *O* nearly perfect, but difficult to obtain.

* All bases calculated as soda. Lime and magnesia were not present.

Crystals striated horizontally. They are commonly terminated at both ends of the prism and are very symmetrical in shape. They average, as thus far seen, about one centimeter in length and thickness, with *O* and *I* as predominating planes (fig. 1).

Sometimes the crystals are confusedly grouped (fig. 2), as from a common center, much like the aragonite from a noted European locality. For some late years mineralogists have received from several localities in the far West groups of tabular crystals that were hexagonal in appearance, very impure in composition, and to which the name of aragonite has

1.



2.

been attached. For the most part they are simply calcium carbonate mixed with sand and mud, and are without cleavage. It is very probable that they are pseudomorphs after the sodium sulphato-carbonate here described. In particular I refer to crystals which I have seen credited to Colorado and to Nevada.

The crystals here analysed were found with salt, thenardite, tincal, etc., at the works of the San Bernardino Borax Co., in San Bernardino County, California.

The density of this new California mineral is 2·562. Its hardness, 3·–3·5. It is readily soluble in water. Effervesces with acids. It affords, when dissolved in water, an abundant precipitate of barium sulphate when barium chloride is added to the solution. On addition of silver nitrate to a fresh solution chloride of silver is precipitated, showing that chlorine is also present. Gentle ignition develops no appreciable loss in the weight of the mineral.

The crystals are transparent to semi-opaque, with a white waxy color inclining to yellow. Surfaces never highly polished nor very smooth.

The definite formula deduced from Mr. Mackintosh's analysis, taken together with the form, warrants me in announcing this as a new mineral species. I therefore propose for it the name of Hanksite, after Professor Henry G. Hanks, of California, to whom we are so largely indebted for our knowledge of the minerals of the Pacific coast.

Newark, N. J., May 23, 1885.

ART. XX.—*Mineralogical Notes;* by EDWARD S. DANA and SAMUEL L. PENFIELD.

1. *A large crystal of Hanksite.*

SOME two years since Professor G. J. Brush placed in our hands for examination a large crystal, or rather group of crystals, of an anhydrous sulphate related to thenardite. The specimen had been received by him from Professor J. S. Newberry, who stated that he had purchased it in California but was unable to learn the exact locality from which it came. The examination proved it to be probably hexagonal in crystalline form, and in composition to consist of sodium sulphate and carbonate in the ratio of 4:1. Feeling reluctant to attach a new name to a mineral of which only one specimen was in hand, and that from an unknown locality, we postponed the publication of our results until some further facts should come to light. The same mineral has now been re-discovered and in specimens so satisfactory as to justify their receiving the name Hanksite, given by Mr. Hidden.

The specimen examined by us consisted of a low hexagonal prism, measuring transversely 75^{mm}, and in a vertical direction 20^{mm}; this prism is penetrated by several other similar tabular crystals but in varying positions, so that no general law of twinning can be given. The basal edges were irregularly replaced by pyramidal planes. Apparently the form is hexagonal, the prism and pyramid both being present, and the measured angles of the former showing very little variation from the required 60°. The analogy of the artificial sulphates of sodium and potassium suggested, however, that the form might be really orthorhombic, and the hexagonal aspect due to twinning. The optical examination made to settle the question was not satisfactory because the crystal contained so much mud as impurity as to be transparent only in spots. Some points were found, however, which gave an obscure uniaxial figure with negative double refraction; but this question might not be regarded as satisfactorily settled were it not for the excellent results which Mr. Hidden's crystals have afforded. The pyramidal plane spoken of was rough and rounded and was only distinctly seen on part of the edges. The approximate angle (supplement) measured on the basal plane is 43°, which, referred to the vertical axis assumed by Mr. Hidden, gives a symbol $\frac{4}{3}(40\bar{4}5)$; required 43° 8′.

An analysis of the mineral gave (Penfield) the following results, which are almost identical with those of Mr. Mackintosh:

		Ratio.				
SO_3	43·59	·545	and	·545	=	43·59 SO_3
Na_2O	40·86	·659		·536	=	33·23 Na_2O
				·123	=	7·63 Na_2O
CO_2	5·42	·123		·123	=	5·42 CO_2
K	2·33	·060				2·33 K
Cl	2·13	·060				2·13 Cl
Insol.	4·41					
Ign.	1·32					
	100·06					

This corresponds then to

Na_2SO_4	76·82
Na_2CO_3	13·05
KCl	4·46
Insol.	4·41
Ign.	1·32
	100·06

The insoluble portion is apparently clay; a section examined in the microscope showed the impurity densely distributed in bands parallel to the prismatic faces. The fact that in the analysis the potassium and chlorine are present in exactly the amounts required to form potassium chloride may be only a coincidence, and the chlorine may in fact be combined with sodium, and the potassium may in part replace the sodium in the sulphate. It is immaterial which explanation is adopted, but in any case it is quite certain that the potassium (or sodium) chloride is present as an impurity, for in the thin section numerous rectangular crystals, some of them apparently cubes, were visible. It seems proper, therefore, to deduct these elements from the analysis, leaving only the sodium sulphate and sodium carbonate. The result, calculated to 100 per cent, is

Na_2SO_4	85·48
Na_2CO_3	14·52

This corresponds, though approximately only, to the formula

$$4Na_2SO_4 + Na_2CO_3$$

which requires

Na_2SO_4	84·27
Na_2CO_3	15·73
	100·00

2.—*An artificial crystallized Lead Silicate.*

We are indebted to the late Professor Silliman for a specimen of an artificial crystallized lead silicate, which had been obtained by him from the Desloge Lead Company, Bonneterre, St. Francois County, Missouri. The specimen consists chiefly of a brownish-red substance with resinous luster somewhat resembling sphalerite, associated with octahedral crystals of magnetite and cleavable galena. In small cavities in the mass and over the surface are numerous crystals, mostly stout hexagonal prisms, which, as is proved later, consist of the same material as the mass of the specimen. These crystals in color and form very closely resemble much of the vanadinite of Arizona, and, before the history of the specimen was known, they were referred to that species almost without question. Later, however, it was learned that the specimen was artificial in origin, and according to the chemist of the company was a lead silicate. A preliminary chemical examination proved that to be true, and a complete analysis was accordingly made of the hexagonal crystals and also of the massive substance.

The crystals spoken of vary in length and thickness from 1 to 3^{mm}. They show ordinarily only the planes of the unit prism I $(10\bar{1}0)$ and the basal pinacoid O (0001); rarely, however, the basal edges of the prism are rounded and in a few instances distinct planes were observed. The best defined of these gave an approximate angle of 50° on the basal pinacoid

$$O \wedge p,\ 0001 \wedge 10\bar{1}1,\ = 50°.$$

This gives as the length of the vertical axis

$$c = 1{\cdot}032.$$

A second pyramidal plane (q) gave an angle on the base of 25°, which corresponds tolerably to the symbol $\frac{2}{5}$ $(20\bar{2}5)$, required 25° 29′. Apparently these pyramidal planes are holohedrally developed, so that the crystals would then be referred to the hexagonal system proper, but the material was too scanty absolutely to prove this point. There is some reason to doubt it, however, for on the other side of the same specimen, distant from them hardly an inch, are a few crystals apparently of the same material, but of quite different form. These are thin tabular crystals showing only the basal pinacoid and a rhombohedron; the measured angle for this is 67°, which, referring it to the above axis, would give it a symbol $2R$, or π $(20\bar{2}1)$. The calculated angle is

$$O \wedge 2R,\ 0001 \wedge 20\bar{2}1,\ = 67°\ 12′.$$

The quantity of these tabular crystals was too small to admit of its being proved that they have the same composition as the hexagonal prisms, but everything points to that conclusion.

The substance was readily soluble in even very dilute, cold nitric acid: the solution upon evaporation yielded gelatinous silica. Before the blowpipe readily fusible. Specific gravity of crystals 5·92. For analysis the compound was dissolved in cold, dilute nitric acid and the insoluble magnetite filtered off. Two analyses were made (Penfield); for the first (I) only distinct crystals were taken, of which ·7073 grams were selected; the result after deducting 0·44 per cent of magnetite is given below. The second analysis (II) was of the crystalline part of the slag. The result is given after deducting ·207 per cent of magnetite. The presence of a trace of carbonic acid, and a very minute trace of phosphoric acid was distinctly proved.

I. Crystals.		Ratio.		II. Massive portion.		Ratio.	
SiO_2	17·17	·286		SiO_2	16·00	·267	
PbO	72·39	·325		PbO	75·26	·338	
FeO	0·51	·007		FeO	0·74	·010	
CaO	7·48	·134	·486	MnO	0·17	·002	·476
MgO	0·56	·014		CaO	6·15	·110	
Na_2O	0·35	·006		MgO	0·50	·012	
				Na_2	0·24	·004	
				CO_2	trace		
	98·46				99·06		

The ratio in I for $SiO_2 : RO = ·286 : ·486 = 1 : 1·70 = 4 : 7$ nearly. For II the ratio is $SiO_2 : RO = ·267 : ·476 = 1 : 1·78 = 4 : 7$ nearly. The agreement between these shows that the formula, $R_7Si_4O_{15}$, must express very closely at least the true composition of this artificial lead silicate. The occurrence of so rare a compound is especially interesting in connection with the recent discovery of native lead silicates, notably at Långban, Sweden.

These natural lead silicates include the three following from Långban: ganomalite, a silicate of lead and manganese with small quantities of lime and magnesia; hyalotekite, a silicate of lead, barium and calcium; melanotekite, a silicate of lead and iron. To these should be added kentrolite, from southern Chili, a silicate of lead and manganese. All of the minerals named are crystalline in structure, but kentrolite alone has been found in distinct crystals. We do not know that any artificial crystallized lead silicate has been described hitherto.

ART. XXI.—*The amount of moisture which Sulphuric Acid leaves in a Gas;* by EDWARD W. MORLEY.

BERZELIUS and Dulong,* about 1820, and Erdmann and Marchand,† about 1842, employed calcium chloride in determining the atomic weight of oxygen, and were probably not aware that it leaves unremoved a comparatively large amount of water. Dumas,‡ in 1842, and Pettenkofer,§ in 1862, mentioned as well known, the fact that calcium chloride will not dry a gas as completely as sulphuric acid. Favre,‖ in 1844, proved that sulphuric acid at ordinary temperatures dries a gas so completely that neither sulphuric acid at −17° C. nor phosphorus pentoxide will absorb a sensible quantity of moisture from 40 liters of gas, nor even from volumes "bien plus considérables." He also attempted¶ in a most ingenious way to determine whether a gas dried by either of these agents was absolutely dry. He passed air dried as perfectly as possible over red-hot copper, and then again through a drying tube. In one experiment, 148 liters of air were reduced to 117 liters of nitrogen, and deposited ·0025 gram of water; in the other, 110 liters of air were reduced to 87 liters of nitrogen, and deposited ·0015 gram of water. Hence he concluded that a liter of gas dried by sulphuric acid or phosphoric oxide contained not more than ·00006 or ·00008 gram of water.

He also proved** that no other force than the tension of the vapor of water causes it to be retained in certain gases. Favre further proved,†† as did Regnault in 1845,‡‡ that drying tubes of no large dimensions are required to utilize the whole drying power of the drying agent with which they are filled. In 1864 and again in 1865, Fresenius§§ published experiments, which, if they were affected by no source of error at that time unsuspected, would show that sulphuric acid leaves one or two decimilligrams of moisture in a liter of gas. But in 1876, Dibbits‖‖ published experiments in which precautions were taken against the leakage of moist air through caoutchouc connectors, which showed that 308 liters of air dried by sulphuric acid at ordinary temperatures gave up but 7 decimilligrams of moisture to phosphorus pentoxide.

Dibbits also proposed a method for solving the remaining

* Ann. Chim. Phys., 2d Series, vol. xv, p. 388.
† Journ. Prakt. Chemie, vol. xxvi, p. 464.
‡ Ann. Chim. Phys., 3d Series, vol. viii, pp. 193, 210.
§ Lieb. Ann. Supp., vol. ii, p. 29.
‖ Ann. Chim. Phys., 3d Series, vol. xii, p. 223.
¶ Ibid., vol. xii, p. 225.
** Ibid., vol. xii, p 227.
†† Ibid., vol. xii, 228.
‡‡ Ibid., vol. xv, p. 152.
§§ Zeitschr. Anal. Chem., vol. iv, p. 180.
‖‖ Zeitschr. Anal. Chem., vol. xv, p. 160.

question: How much moisture is left in a gas dried by phosphorus pentoxide? He proposed to evolve a gas of which we might be certain that it contained no water, to pass it into water, and then to dry it with phosphorus pentoxide. He suggested the evolution of dry oxygen by heating fused potassium chlorate. Whether perfectly dry oxygen could be thus obtained remains to be seen; the task of keeping up a suitable current of oxygen till a few hundred liters shall pass the absorption tubes would involve a good deal of labor.

Desiring to know the amount of water which sulphuric acid or phosphorus pentoxide fails to remove from a gas, I succeeded in devising a method which has made the solution of the problem easy. It permits the determination of the absolute amount of moisture left in a gas by any drying agent; the maintaining a slow current of air for days or weeks demands attention for only some five minutes each day, so that very large volumes of air may be used, at small velocities, and even if the residual moisture is as little as a hundredth or a thousandth of a milligram in a liter, it may be determined with any needed accuracy.

I devised the method with the intention of applying it first to phosphorus pentoxide. But in the third number of the Zeitschrift für analytische Chemie for 1884, Mathesius made certain statements about the use of sulphuric acid in drying tubes, in consequence of which I first undertook the study of the absolute amount of moisture left in a gas by this drying agent.

The paper of Mathesius raised a preliminary question which had to be answered. He found that certain drying tubes filled with sulphuric acid, of specific gravity 1·84, when used to absorb moisture as in organic analysis, lost weight at the rate of five or more decimilligrams an hour. This statement must be taken as referring to sulphuric acid supposed to be pure; because a statement that impure sulphuric acid contained some volatile impurity would hardly be worth publication; and also because, in order to lessen the loss of weight in his drying tubes, Mathesius diluted the acid somewhat, probably supposing that the vapor of sulphur trioxide escaped and occasioned the loss of weight.

It is difficult to believe that either water or sulphur trioxide can be given up by pure sulphuric acid to a current of gas in any such quantity as Mathesius observed. Regnault* determined the tension of the vapor of water given off at 20° C. by sulphuric acid of the formula SO_3+2H_2O. This is ·15 millimeter, so that a liter of absolutely dry air passing through such acid would take up at this temperature ·16 milligrams of water.

* Ann. Chim. Phys., 3d Series, vol. xv, p. 179.

He gives no results for acid more concentrated than this; but from a comparison of the results for more dilute acids, it is difficult to believe that an acid containing half a molecule of water and one molecule of the monohydrated acid would give up to a liter of absolutely dry air as much as the twentieth of a milligram of water at ordinary temperatures.

And as to the evaporation of sulphur trioxide from sulphuric acid: Dumas* passed 20 liters of air through pure sulphuric acid, and into solution of barium chloride, which preserved "une limpidité absolue." But if the loss of weight observed by Mathesius was due to the escape of sulphur trioxide, Dumas should have obtained not only a visible but a weighable precipitate.

But while we may dismiss the idea that sulphur trioxide escapes from sulphuric acid in drying tubes in ordinary conditions in any such quantities as several decimilligrams an hour, it was necessary for the determination of the absolute amount of moisture left unabsorbed by sulphuric acid that the amount of sulphur trioxide volatilized should be accurately determined. For this purpose I made several experiments. In one of them, a wash bottle and a Winkler's absorption tube were filled with pure sulphuric acid. This acid I distilled from a pure acid, rejecting the first and the last fifth. Its specific gravity at 22° and at 16·8° C., compared with water at 4°, weights being reduced to a vacuum, and the thermometer being corrected for error of zero point, was found to be 1·8344 and 1·8394. A current of air was aspirated through a gas-meter, through the wash bottle of acid, through the absorption tube with acid, through an empty tube two meters long, through a plug of glass wool, and through an absorption tube with pure water. The acid in the absorption tube occupied about two meters and a half; the water in the other absorption tube occupied about a meter. The parts of the apparatus were fused together. When 6800 liters had passed, not too rapidly, the sulphuric acid in the water was determined as barium sulphate, and found to be 3·1 milligrams. In a second experiment at a somewhat lower temperature, ·7900 liters were passed and 2·5 milligrams of acid were found in the second absorption tube. Several experiments were made in which air passed, at the rate of two liters an hour, into a solution of barium chloride; in which experiments neither myself nor Dr. Spenzer, my assistant, could detect any trace of a precipitate till the third day.

With the degree of approximation thus far obtained, therefore, we may conclude that a liter of air passed through sulphuric acid of the specific gravity of 1·84 will take up something like the two thousandth or three thousandth part of a milligram of sulphur trioxide at ordinary temperatures.

* Ann. Chim. Phys., 3d Series, vol. viii, p. 204.

This being determined, the way was clear to determine the absolute amount of moisture left in a gas by sulphuric acid. To Liebig's potash bulbs I fused a sixth bulb, connected with the others by a capillary tube of so small bore that when a vacuum was maintained at one end, one or two cubic centimeters of air would pass through it in a minute. In this sixth bulb I placed sulphuric acid so diluted with water that air passing through it would take up a certain small amount of water. In the bulbs which belonged to the original apparatus was placed sulphuric acid of specific gravity 1·8381 at 18° C., compared with water at 4° C., weights and thermometer being corrected.

In use, a partial vacuum was maintained in the five bulbs containing strong acid, while the dilute acid was in contact with air at ordinary pressure. Air in passing from the dilute acid through the constriction towards the strong acid would therefore expand a number of times depending on the pressure in the partial vacuum. The air before entering the dilute acid was made as dry as sulphuric acid can render a gas; it took up water from the dilute acid; it was expanded; the increased volume was made as dry as sulphuric acid can render a gas.

Let us imagine, for the sake of clearness, that the expansion in passing the constriction was ten times, that five liters of air entered the dilute acid, and that therefore fifty liters passed out of the strong acid. Let us also make two alternative suppositions in order; first, that sulphuric acid makes a gas perfectly dry, and second, that it leaves a hundredth part of a milligram of water in a liter of gas.

If, according to the first supposition, sulphuric acid makes a gas perfectly dry, the five liters of dry air which enter the six-bulb apparatus carry into it no water. In the sixth bulb they take up a small quantity of water. Passing the constriction, they become fifty liters. The sulphuric acid makes the fifty liters perfectly dry, and no water is carried out of the apparatus. Therefore the only effect changing the weight of the apparatus is the escape of sulphur trioxide, the amount of which is approximately known.

But, secondly, if sulphuric acid leaves a hundredth of a milligram of water in a liter of gas, the five liters of air entering the apparatus carry into it one-twentieth of a milligram of water. In the sixth bulb, more water is taken up. The five liters expand to fifty. Now the drying such a gas as air is simply a process of reducing the vapor tension of the accompanying vapor of water. One liter of air dried by sulphuric acid will contain water possessing a certain tension, whatever be the pressure of the air. At least Regnault proved this to be true within one per cent. The fifty liters of air will therefore

carry out ten times as much moisture as the five liters brought in. Neglecting for a moment the evaporation of sulphur trioxide, the apparatus will lose nine twentieths of a milligram in weight. Conversely, if we knew the expansion to be ten times, and the entering air to be five liters, and the loss of weight to be ·45 milligram, we could compute the water remaining in each liter to be 0·01 milligram.

In applying this principle, it was necessary to avoid errors due to leakage of moist air into the apparatus during the long time through which an experiment lasted, and to provide for weighing the six-bulb apparatus so accurately as to make certain the detection of a total effect of a few tenths of a milligram. I secured sufficient accuracy in weighing by using as a counterpoise an apparatus of the same shape and same kind of glass, filled with the same acid, and interposed in the same current of air. To these I fitted ground glass caps as accurately as I could, so that I could leave the two apparatus on the balance for several days without any change in their relative weights; of course after applying corrections for the state of the barometer and thermometer.

I also fitted to the two apparatus just named, a third, which prevented the diffusion of moist air backward from the vacuum, and a fourth which dried the air before it entered the first and second apparatus, all, to each other, by glass tubes with joints carefully ground which were made tight with a fat from which all matter volatile at common temperatures had been removed. In this way, I could leave the apparatus for weeks with the certainty that moist air could not enter the apparatus.

The measure of the volume of air which enters the apparatus and of the expanded volume which leaves it is easy. The third drying tube which prevents the diffusion of moist air backward was fused, together with a barometer gauge, to a tube leading to an air-tight reservoir of 54·1 liters capacity. When all the drying tubes were in place, the pressure in the reservoir was reduced to such a fraction of an atmosphere that the air passed through the last five bulbs of the six-bulb apparatus at the rate of about two liters an hour. This pressure was observed on the barometer gauge. Call the pressure *a*. On the next day, or sometimes in twelve hours, the pressure was again observed. Call the second pressure *b*. The pressure in the reservoir was then again reduced, and the apparatus was ready for another day of action.

Now, disregarding variations of temperature and supposing the barometer constant, remembering that the expansion of the air takes place so slowly that no cooling effect is sensible, we can easily compute the volume of rarefied air which has passed

out of the six-bulb apparatus while the pressure has increased from a to b. For this purpose put

w = the weight of the air which would pass through the constriction in the unit of time, if a perfect vacuum were maintained on one side, and the barometric pressure on the other.
x = the pressure in the reservoir.
h = the height of the barometer, assumed constant.
t = the time.
u = the weight of air in the reservoir at the pressure x.
c = the capacity of the reservoir.
l = the weight of a liter of air at the temperature and pressure of the air during the experiment.
V = the volume of rarefied air passing out of the apparatus while the pressure rises from a to b.

The weight of air passing out of the six-bulb apparatus in the unit of time, when the pressure in the vacuum is not zero, but x, may be written $wf(x)$. At normal pressure, its volume would be $\frac{w}{l}f(x)$, but under the pressure x, its volume would be $\frac{h}{x}\frac{w}{l}f(x)$, and we therefore have $d\mathrm{V}=\frac{h}{x}\frac{w}{l}f(x)dt$. Also it is obvious that $\frac{x}{h}=\frac{u}{cl}$, so that $du=\frac{cl}{h}dx$; and obviously $du=wf(x)dt$.

From the last two equations, we find $dt=\frac{cl}{hwf(x)}dx$; and substituting this value we get $d\mathrm{V}=c\frac{dx}{x}$.

Therefore $$\mathrm{V}=c\int_{x=a}^{x=b}\frac{dx}{x}=c\log\frac{b}{a}.$$

This is the volume of rarefied air which passes the constriction while the pressure rises in the reservoir from a to b. Its volume on entering is computed in an obvious manner.

I have so far made three experiments, as follows:

	1.	2.	3.
Air entering apparatus = n	27 l.	23 l.	58 l.
Mean temperature = t	16° C.	15° C.	19° C.
Air leaving apparatus	286 l.	228 l.	757 l.
Excess leaving	259″	205″	699″
Liters an hour	1·6″	1·4″	1·2″
Dilute acid, specific gravity	1·707	1·707	1·566
Vapor tension of water from such acid at temperature t	·48^{mm}	·43^{mm}	1·85^{mm}
Milligrams water taken up by n liters air, at t { *computed*	13^{mg}	10^{mg}	106^{mg}
Specific gravity strong acid at $\frac{18°}{4°}$	1·8381	1·8381	1·8388
Loss, decimilligrams	5½	4½	18

Experiments 1 and 2 were parts of the same experiment which was interrupted to see if the loss of weight were proportional to the amounts of air in the line marked "excess leaving." In all three experiments, 1163 liters more passed out than entered the apparatus, the sum of the losses in weight is 2·8 miligrams. The amount of sulphur trioxide which escaped may be computed at ·4 milligram. The remaining 2·4 milligrams is the weight of aqueous vapor carried out of the apparatus by 1163 liters of air. The quantity subtracted is affected with some uncertainty, since the air used in the experiment on the evaporation of sulphur trioxide was not purified from organic matter, and there may have been reduction of the acid to the dioxide, and reoxidation to sulphuric acid. But with the approximation so far obtained, the water which strong sulphuric acid fails to remove from a slow current of air is about the four hundred and fiftieth or five hundredth part of a milligram in a liter of air.

Dibbits* showed that 308 liters of air dried by sulphuric acid gave up ·7 milligram to phosphorus pentoxide. It is curious that this is the quantity which my experiments show to be left by sulphuric acid in that quantity of air. The obvious inference may be true, but is not safe. I shall hope to repeat these experiments on the evaporation of sulphur trioxide from sulphuric acid with purified air, and those on residual moisture left in a gas by the acid with some form of apparatus permitting more accurate weighing than Liebig's bulbs.

749 Republic Street, Cleveland, Ohio, May 25th, 1885.

Art. XXII.—*Local Deflections of the Drift Scratches in Maine;* by G. H. Stone.

On almost every glaciated surface in Maine may be found isolated drift scratches aberrant both in direction and outline. Often these are somewhat curved and may grow deeper toward their south ends where they usually terminate abruptly. In a few cases I have found reversed curves making the scratch resemble the mathematical sign of integration. They sometimes vary 10° or even 20° from the average direction of the glaciation and hence they often intersect other scratches near them. Indeed it is the exception to find the glacial scratches exactly parallel even when adjacent, and it is often by no means an easy task to decide which of a given series of scratches most nearly represents the true direction of the glacial movement at that point. The writer is persuaded that the time has come for glacialists to unite in adopting some more

* Zeitschr. Anal. Chem., vol. xv, p. 160.

accurate system of measurements than has heretofore prevailed. A full discussion of this subject is reserved for another occasion. For our present purpose it is assumed that in order to prove by means of glacial scratches, that the ice at a given place moved in different directions at different times, it is needful to prove that there are intersecting series of scratches at that point.

The following instances of local changes in the direction of the ice-flow in Maine have been reported. In the Maine Geological Report for 1861 (p. 262), Professor C. H. Hitchcock reports intersecting drift striæ at Chamberlain Lake in northern Maine, and perhaps his observations on the drift of the upper Saint John Valley may indicate local glaciation. Professor Hitchcock has also described a *roche moutonneé* in York County, Me., on the stoss side of which the drift scratches bear southeastward, while on the lee side they bear southwestward. Professor G. L. Vose was the first (American Naturalist, vol. ii, p. 28) to report the signs of a local glacier in the Androscoggin Valley. This glacier extended from the White Mountains eastward to near West Bethel, Me., as is proved by the moraines and by the glacial scratches which, near the bottom of the valley, are nearly parallel with the course of the valley, while the glaciation of the higher hills and the surrounding region is nearly at right angles to this direction. These observations regarding the local Androscoggin glacier, the writer has carefully verified. The other localities named have not been visited by me. Professor F. C. Robinson of Bowdoin College, has also informed me that he has found intersecting drift scratches on the bank of the Penobscot River, a few miles west of Chesuncook Lake.

During the past summer the writer has discovered three other localities showing intersecting drift striæ. That the secondary glaciation was not sooner discovered is due to the fact that the slates east of Waterville weather quite readily. The later scratches are shallow, and long after they have been obscured by weathering, the earlier and deeper ones remain quite distinct. This gives an appearance of freshness to rock exposures, which is very deceptive.

1. *The Sebasticook Valley Locality.*

The Sebasticook River flows from the east into the Kennebec River at Waterville. Numerous observations of the drift striæ on both sides of the Sebasticook show that there is an area several miles long in the towns of Winslow, Benton and Clinton, where there are two and in a few places three superposed systems of scratches. In a few places very near the Sebasticook, the later scratches are very confused, pointing in many directions, whether from berg drift or ice gorges of the river is yet

uncertain. The intersecting systems of scratches were traced to within one-half a mile of the Kennebec River, and if any fresh exposures could have been found, they might perhaps have been traced quite to that river. No opportunity has yet offered for excavation, which will be necessary for determining the limits of the area showing deflections in the direction of the ice-flow. The facts will be sufficiently indicated by a few typical examples. All the angles given in this paper are corrected for the magnetic variation, and are therefore azimuths, not bearings.

North Vassalboro, S. 11° W.

S.E. part of Winslow, older striæ S. 4° E.; newer, S. 24° E.

S. part of Benton, older S. 6° W.; newer S. 26° W.

Three miles S. of Clinton village, S. 24° W.

Benton, N. side of Sebasticook, oldest series S. 14° W.; next later S. 24° W.; and a very faint series comes last, S. 34° E.

Winslow, one-half mile E. of Kennebec, older S. 24° W.; later, S. 69° W.

These observations plainly show movements of the ice in more than two directions. The eastward flow in the S.E. part of Winslow probably indicates a local movement down the Sheepscot Valley. The valleys of the Kennebec, the Sheepscot and the Penobscot are more favorably situated for local movement than any other of the larger river valleys of Maine, though perhaps the valley of the St. Croix should be added to this list. The shorter valleys of the St. George, the Union, the Narraguagus, the Machias, and the rest of the small coast streams are equally favorably situated in the matter of direction, as they lie nearly north and south, but they do not penetrate the high ranges of hills which formed a barrier to farther ice-flow southward after the ice became less than about 500 feet thick. Near the Sebasticook, the latest scratches are quite shallow, and have not effaced the earlier ones as they have done in the track of the local Androscoggin glacier. A fair inference is that at the time when these latest scratches were made, the ice was becoming thin and that the flow was not long continued in the direction of the latest glaciation. Further exploration will be needed in order to bring out all the facts; thus far we are justified in regarding these local deflections as an incident of the decay of the great ice-sheet, at a time when the local topography affected the ice-movements much more than during the time of maximum glaciation.

2 *and* 3. *The Belfast and the St. George River Localities.*

These localities are so closely connected that they may best be described together. For about ten miles north of Union Village, the St. George River (St. George on the maps but

locally known as George's River) flows in a narrow valley between steep ranges of hills. The ridge on the west side of the valley rises from 200 to 500 feet above the river, that on the east from 600 to 1100 feet above it. The last named range chiefly lies in the towns of Hope and Union, and rises to an elevation of 1240 feet above the sea. East of it is an irregular clump of high peaks and ridges in Camden and Lincolnville.

Near Union Village the observed direction of the drift scratches is S. 15° W. Near the St. George River from the north line of Union to the north line of Appleton, S. 25° to 30° W., approximately parallel with the valley. Near North Appleton the valley series of scratches is crossed by a later series at an angle of about 75°. These later scratches were found on the east side of the valley, about 100 feet above the river, and run obliquely down the hill toward the bottom of the valley and almost due west. The limits of this area of local ice-movement have not been determined.

If we leave the valley of the St. George at Searsmont and pass eastward, our course will lie two or three miles north of the high hills of Hope and Lincolnville before referred to. The westward deflection of the glaciation increases as we proceed. In the south part of Belmont, about five miles east of Searsmont, the direction of drift striæ is S. 35° to 37° W. Yet this place is in the broad valley of a stream which flows southeastward to Lincolnville Village, while to the south lies a narrower low pass through Hope and West Camden. Here then, although a natural drainage slope lay off to the southeast, and a favorable pass to the south, yet the ice bore off over a rolling plain to the southwest into the narrow valley of the St. George. Three miles farther east in Belfast, the scratches follow the valley of Little River, S. 10° to 20° E. Numerous exposures of the rock in Belfast and Morrill show uniformly an eastward trend of the drift-scratches, sometimes as much as S. 40° E.

About three miles N.W. of Belfast City there are several places where are preserved portions of a system of drift-scratches which has been nearly effaced by a later glaciation. The local rock is a hard quartzitic slate, well adapted both for resisting glacial corrasion and for preserving the scratches under atmospheric exposure. Usually, when traceable, the earlier scratches have been intersected and nearly obliterated by the later, but at one place the earlier ones were perfectly preserved in a depression of the rock at the southeastern base of a little ledge or steep escarpment barely from half an inch to two inches in height. The line or front of the little precipice happened to lie parallel with the earlier ice-movement and hence offered no resistance to it. The gentle depression was

glaciated S. 10° E. to the very base of the scarp. But when the direction of the ice-flow changed to S. 30° to 35° E., then the steep scarp protected a portion of the depression, and a strip from two to eight inches wide was left in its lee wholly untouched by the later glaciation. Over all the rest of a rock exposure fifteen feet in diameter, the later glaciation had wholly effaced the earlier.

It thus appears, that at one time, the high hills of Hope, Lincolnville and Camden (the "Camden Hills" of the mariners) formed a great barrier and forced the ice to flow around them both to the east and the west. In doing this they were aided by the topographical features of the country lying to the north of them, where is a great gently rolling plain. During Champlain time, an arm of the sea extended up the St. George Valley to Searsmont and thence eastward through Belmont and Morrill to Belfast. The average elevation of the country lying between the St. George Valley at Searsmont and the head of Belfast Bay is rather less than 200 feet. Megunticook and its associated peaks rise from 600 to 1000 feet above this plain. When the ice was thickest the flow was directly over these hills, but when the thickness was 1000 feet or less, this would manifestly be impossible. My exploration reached only the northern and western bases of these hills, and a thorough exploration will be needed in order to trace all the deflections of ice-movement which would naturally take place in so uneven a country. A single item of detail will be referred to in closing. As has been stated above, in the southern part of Belmont the flow was southwestward down the St. George Valley, rather than south or southeastward, though the latter route presents a more favorable slope through a somewhat level valley from one to two miles wide. No lateral moraines are found near the north ends of the valleys which lie between the high hills of Hope, Camden, etc. Apparently, then, these valleys were filled with embayed ice. That is, instead of a series of local glaciers penetrating the hilly region, the valleys were filled with stationary ice, at least it was stationary enough to unite with the hills to form a great barrier which caused the main ice-flow to take place around the eastern and western bases of this system of hills. It will be proper to add that the direction of the drift-scratches in the vicinity of Belfast bears a significant relation to the glacial gravels of the region. Five systems of these gravels converge to Belfast Bay, all roughly parallel with the glaciation. These deposits are in several respects different from the other Kame or Osar gravels of Maine which I have heretofore described, at least from those of the interior of the State where no evident signs of local ice-movements have been discovered.

Colorado College, Oct. 29, 1884.

ART. XXIII.—*Successional relations of the species in the French Old-Tertiary;* by OTTO MEYER, Ph.D.

IN a former article * I have shown that in the American Old-Tertiary formation many species can be traced along through the succeeding strata, and that the similar succeeding forms are apparently connected by descent. In the second part of this article † I said that the same phenomenon is manifest also in the French Old Tertiary formation. The following table may illustrate this. For the principles which have guided me in making out this genealogy, I refer to this Journal, vol. xxix, p. 458. In preparing it I have used only the material in my own collection, and for this reason the table is very incomplete. Naturalists with more material from French localities than I have may complete it and perhaps correct it in some points. In comparisons like these I think it best to avoid the use of descriptions and figures.

The determinations of the species enumerated in the table were made by Mr. Cossmann, in Paris; and I have adhered to his determinations, even where I am of different opinion; in many cases I would not make specific differences where they are made by Deshayes. My purpose here is only to call attention to the fact that evolution is illustrated also by the species of the French Old-Tertiary. Mr. Cossmann is now occupied with a revision of the species of Deshayes.

	LOWER EOCENE.	MIDDLE EOCENE.	UPPER EOCENE.	OLIGOCENE.
		Lamellibranchiata.		
1		Ostrea flabellula *Lam.*	Ostrea cubitus *Desh.*	
2	Ostrea angusta *Desh.*	Ostrea cyathula *Lam.*	Ostrea cucullaris *Lam.*	
3	Anomia primæva *Desh.*	Anomia tenuistriata *Desh.*		
4	Arca modioliformis *Desh.*	Arca modioliformis *Desh.*	Arca Rigaultiana *Desh.*	
5		Arca condita *Desh*	Arca planicosta *Desh.*	
6	Pectunculus polymorphus *Desh.*	Pectunculus pulvinatus *Lam.*		
7	Pectunculus terebratularis *Lam.*			Pectunculus obovatus *Lam.*
8	Limopsis lentiformis *Desh.*	Limopsis granulata *Lam.* sp.		
9		Trigonocœlia deltoidea *Lam.*	Trigonocœlia media *Desh.*	
10		Nucula Parisiensis *Desh.*	Nucula lunulata *Nyst.*	
11	Cardita planicosta *Lam.*	Cardita planicosta *Lam.*		
12	Cardita Prevosti *Desh.*	Cardita asperula *Desh.*		
13	Cardita imbricata *Lam.*	Cardita imbricata *Lam.*	Cardita propinqua *Desh.*	
14		Crassatella compressa *Desh.*	Crassatella rostralis *Desh.*	

* This Journal, xxix, 457–468, 1885. † Ibid. xxx, 66.

	LOWER EOCENE.	MIDDLE EOCENE.	UPPER EOCENE.	OLIGOCENE.
15	Lucina discors *Desh.*		Lucina Ermenonvillensis *d'Orb.*	
16	Lucina proxima *Desh.*	Lucina Saxorum *Lam.*		
17		Lucina elegans *Defr.*	Lucina elegans *Defr.*	
18	Diplodonta duplicata *Desh.*		Diplodonta elliptica *Desh.*	
19		Cardium obliquum *Lam.*	Cardium Bouei *Desh.*	
20	Cardium hybridum *Desh.*	Cardium porulosum *Lam.*		
21		Cardium granulosum *Lam.*		Cardium scobinula* *Mer.*
22	Cytherea proxima *Desh.*		Cytherea striatula *Desh.*	
23	Cytherea fastidiosa *Desh.*			Cytherea incrassata *Sow.*
24		Cytherea semisulcata *Lam.*†	Cytherea polita *Lam.*†	
25		Cytherea analoga *Desh.*	Cytherea cuneata *Desh.*	
26	Tellina pseudorostralis *d'Orb.*	Tellina rostralis *Lam.*		
27		Tellina donacialis *Lam.*	Tellina parilis *Desh.*	
28	Tellina decorata *Watel.*		Tellina symmetrica *Desh.*	
29	Mactra Levesquei *d'Orb.*	Mactra semisulcata *Lam.*		
30	Corbula gallicula *Desh.*	Corbula gallica *Desh.*		
31	Corbula striatina *Desh.*	Corbula Lamarcki *Desh.*		
32	Corbula muricina *Lévesq.*	Corbula minuta *Desh.*		
33	Corbulomya seminulum *Desh.*		Corbulomya complanata *Sow.*	
		Glossophora.		
34	Delphinula turbinata *Desh.*	Delphinula turbinoides *Lam.*	Delphinula turbinoides *Lam.*	
35	Bifrontia Laudunensis *Desh.*	Bifrontia serrata *Desh.*		
36	Turritella Dixoni *Desh.*	Turritella carinifera *Desh.*	Turritella copiosa *Desh.*	
37	Calyptræa Suessoniensis *Desh.*	Calyptræa lamellosa *Desh.*		Calyptræa labellata *Desh.*
38		Hipponix elegans *Desh.*	Hipponyx patelloides *Desh.*	
39	Natica semipatula *Desh.*	Natica patula *Desh.*		
40	Natica intermedia *Desh.*	Natica depressa *Desh.*		
41		Natica abscondita *Desh.*	Natica abscondita *Desh.*	
42		Natica epiglottina *Lam.*	Natica Noæ *d'Orb.*	
43	Natica separata *Desh.*	Natica semiclausa *Desh.*		
44		Natica acuta *Desh.*	Natica ponderosa *Desh.*	
45	Diastoma variculosum *Desh.*	Diastoma costellatum *Lam.*	Diastoma interruptum *Desh.*	
46		Pyramidella terebellata *Fér.*	Pyramidella inaspecta *Desh.*	
47	Odostomia turbonilloides *Desh.*	Odostomia turbonilloides *Desh.*		Odostomia obesula *Desh.*
48	Turbonilla polygyrata *Desh.*	Turbonilla fragilis *Desh.*		
49		Pseudomelania hordana *Lam.* sp.	Pseudomelania hordana *Lam.* sp.	
50		Pseudomelania lactea *Lam.*		Pseudomelania semidecussata *Lam.*

* Compare the specimens of the Mayence Basin.

† If these two species occur near each other, they must have a very near common ancestor.

	LOWER EOCENE.	MIDDLE EOCENE.	UPPER EOCENE.	OLIGOCENE.
51	Cerithium breviculum *Desh.*			Cerithium Boblayi *Desh.*
52		Cerithium echidnoides *Lam.*	Cerithium pleurotomoides *Lam.*	
53	Cerithium subacutum *d'Orb.*		Cerithium Bouei *Desh.*	
54	Cerithium involutum *Lam.*	Cerithium conoideum *Lam.*	Cerithium Cordieri *Desh.*	
55	Cerithium plicatulum *Desh.*			Cerithium limula *Desh.*
56	Cerithium deceptor *Desh.*	Cerithium perforatum *Lam.*		
57	Cerithium turbinatum *Desh.*	Cerithium interruptum *Lam.*		
58			Cerithium mixtum *Desh.*	Cerithium conjunctum *Desh.*
59		Rostellaria fissurella *Lam.*	Rostellaria lubrosa *Sow.*	
60			Buccinum sabrandei *d'Orb.*	Buccinum Gottardi *Nyst.*
61		Marginella crassula *Desh.*	Marginella Edwardsi *Desh.*	
62		Marginella ovulata *Lam.*		Marginella Stampinensis *St.-M.*
63		Mitra cancellina *Lam.*		Mitra perminuta *Braun.*
64		Voluta spinosa *Lam.*	Voluta depauperata *Desh.*	
65		Oliva nitidula *Desh.*	Oliva Baumontiana *Lam.*	
66		Ancillaria buccinoides *Lam.*	Ancillaria obesula *Desh.*	
67	Ringicula minor *Desh.*	Ringicula ringens *Lam.* sp.	Ringicula ringens *Lam.* (var. Meyer.)	

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On a new general Method for the Determination of Nitrogen.*—The determination of nitrogen in nitro- and azo-compounds is effected by the addition of some reducing material to the soda-lime, by which the nitrogen is yielded as ammonia. Tamm-Guyard proposed sodium acetate, Ruffler, sodium thiosulphate, and Goldberg, stannous sulphide and sulphur. All these are somewhat unsatisfactory as general methods, and Arnold has experimented with a view to improve them. He first used a mixture of acetate and thiosulphate, and afterward two or three per cent of amorphous phosphorus; but without advantage. He then substituted sodium formate for the acetate, using it in connection with sodium thiosulphate and soda lime, and obtained excellent results. The combustion tubes used were from 10–12

mm. diameter. The ammonia was determined by means of a normal hydrochloric acid, standardized by analysis and by pure sodium carbonate. For titering back, one-third normal ammonia solution was used, controlled by oxalic acid. Fluorescein was employed as an indicator, since it can be used in daylight and with artificial light as well. The results of the mixture used in four different proportions, are given. In A, equal parts soda-lime, sodium thiosulphate and sodium formate were employed. In B, two parts soda-lime, one part sodium formate and 10 per cent of sulphur. In C, equal parts soda-lime and formate, with ten per cent sulphur. And in D, two parts thiosulphate, mixed with one part of soda-lime and sodium formate mixed. The latter mixture is preferred by the author who suggests the following points to be observed: (1) A canal in the mass in the front of the tube should be avoided. In filling the tube, the finely pulverized mixture containing the substance is first introduced, the tube held vertically and jarred to compact the mass. Then a mixture (either A or D) is placed in it, and then coarsely pulverized soda-lime. (2) The mass in front must have a definite length. In the analyses given this length was 15 cm., but 20 cm. would be better. (3) The combustion in a 45 cm. tube requires about one hour, a bubble of gas per second passing through the receiver. (4) The process is a failure if the acid becomes turbid or acquires more than a yellow color. (5) Not more than 0·5 gram, or, if the substance contains over 20 per cent nitrogen, not more than 0·3 gram is to be used. (6) The mixture containing the substance should occupy 12 to 15 cm., the mass in front of this 15 to 20 cm. and the soda-lime 5 to 10 cm. of the tube. By this method potassium nitrate gave 13·85, 13·77 per cent N, instead of 13·86; sodium nitroprusside 28·20 and 28·15, instead of 28·13; trinitromethyl-toluidine 21·90, cal. 21·87; ethyl nitrocinnamate 6·01, cal. 6·33; nitrosalicylic acid 7·56, cal. 7·65; strychnine nitrate, 10·60, cal. 10·60; morphine 4·50, cal. 4·62; *m*-nitrocinnamic aldehyde 7·89, cal. 7·91.—*Ber. Berl. Chem. Ges.*, xviii, 806, April, 1885. G. F. B.

2. *On a new method of determining the Heat of combustion of Carbon and of Organic compounds.*—Two difficulties attend the determination of the heat of combustion of carbon and its compounds: one arises from the length of time required, the other from the incompleteness of the oxidation. Berthelot and Vieille have obviated these difficulties by effecting the combustion in oxygen compressed to about seven atmospheres, in a calorimetric bomb; using a weight of combustible such that the oxygen consumed by it does not exceed 30 to 40 per cent of the whole quantity. The ignition is accomplished by a platinum wire heated to redness by electricity and is completed in a few seconds, sometimes with the characteristic noise given by an explosion in a closed vessel. The entire operation does not require more than three or four minutes and is applicable to all substances whose vapor tension at the ordinary temperature is incon-

siderable. The completeness of the combustion was verified by an examination of the products. The heat of combustion thus obtained is of course the heat at constant volume. For carbon this is the same value as that at constant pressure, since the carbon dioxide formed replaces the oxygen volume for volume. For hydrogen compounds, however, the usual corrections are necessary for the condensation of the water vapor. When cellulose in the form of cotton was burned in this way, the ash being deducted, one gram gave 4·2 calories; or one equivalent (162 grams) 680·4 calories. The heat of combustion calculated at constant pressure, the water being in the liquid state, is 681·8 calories. Comparing this value with that of the carbon contained in the cellulose (referred to diamond) 564 calories, it appears that that of the cellulose is in excess 117·8 calories, or about one-fifth. It follows from this that the hydrates of carbon, so-called, contain an excess of energy above that given by the carbon and water which their decomposition would furnish. The authors call attention to the fact that this is also true of incompletely burned charcoal, as for example the *charbon roux* used in making gunpowder; and hence that the energy of a sample of gunpowder due to the carbon it contains cannot be accurately calculated from its percentage composition.—*Bull. Soc. Ch.*, II, xliii, 262, March, 1885. G. F. B.

3. *On a new absorbing agent for Oxygen.*—Von der Pfordten has suggested the use of chromous chloride as an absorbing substance for oxygen. To prepare it, chromic acid is heated with hydrogen chloride until the liquid is perfectly free from chlorine. The green solution of chromic chloride is then reduced by means of zinc, to the blue solution of chromous chloride. This is then poured, in an atmosphere of carbon dioxide, into a saturated solution of sodium acetate, whereby a red precipitate of chromous acetate is produced, which is washed by decantation with carbonic acid water. The precipitate is quite permanent and may be preserved for some time without change in closed vessels filled with carbon dioxide. For use it is converted into chromous chloride by placing it in a test-glass closed by a rubber stopper bored with three holes. Through one of these a funnel passes, furnished with a cock. The others have entrance and exit tubes as usual. When the air is displaced by carbon dioxide, the acetate is placed in the glass in excess, the gas stream continued and hydrochloric acid allowed to flow in and convert it into a blue solution of chromous chloride. When a gas containing oxygen is passed through it the color changes from blue to green. Experiments have shown that an alkaline solution of pyrogallol is entirely unaffected by gas which has passed through the solution of chromous chloride. Hence, hydrogen, carbon dioxide, hydrogen sulphide and the like may be freed from oxygen in this manner.—*Liebig Ann.*, ccviii, 112, March, 1885. G. F. B.

4. *On a Simple Quantitative method of separating Selenium and Tellurium.*—DIVERS and SHIMOSÉ have proposed a method of separating selenium and tellurium founded on their behavior toward sulphurous oxide in presence of sulphuric acid, no hydrochloric acid being present. A mixture of the two substances in the free state is heated with concentrated sulphuric acid in a covered beaker until it is entirely oxidized and converted into a colorless solution, with a deposit perhaps, of tellurium sulphate. A moderately strong solution of sulphurous oxide is then gradually added until the volume is increased at least five-fold, and the solution is heated on the sand bath for some time. The precipitated selenium soon darkens in color and becomes dense without aggregating into masses difficult to wash as it does when heated with hydrochloric acid. After dilution, the solution is filtered through a tared filter, and the precipitate washed, dried and weighed. The tellurium is precipitated from the filtrate by heating with hydrochloric acid and adding sulphurous oxide in the usual way. To test the process, 0·3115 gram Te and 0·3867 gram Se were mixed, dissolved and separated. The tellurium weighed 0·3107 and the selenium 0·3865 gram. In a second experiment the quantities taken were 0·2515 gram Te and 0·3395 gram Se; the quantities recovered were 0·2513 gram Te and 0·3395 gram Se.—*J. Chem. Soc.*, xlvii, 439, June, 1885. G. F. B.

5. *On the Illuminating power of Ethane and Propane.*—P. F. FRANKLAND has been engaged for some time in determining the illuminating power of the hydrocarbons supposed to be present in coal gas. He had previously shown that the illuminating power of ethylene calculated for a consumption of five cubic feet per hour from a referee's burner, is 68·5 candles; and that of benzene was estimated to be six times as great. He has now experimented with ethane and propane, the second and third terms of the paraffin series. The ethane was prepared by the action of the copper-zinc couple upon ethyl iodide in presence of alcohol, and was made to pass slowly, first through bromine and water and then through a solution of sodium hydrate and finally over slaked lime. The product showed on analysis 97·88 per cent of ethane. Burned from a referee's burner and comparison being made with the Methoen standard and with standard candles, the mean result (corrected for five cu. ft. of gas) was 34·99 candles. The propane was prepared by the action of zinc on isopropyl iodide, being passed first through a scrubber containing zinc-copper, then through alcoholic soda, bromine and water, sodium hydrate and slaked lime. The gas contained 95 per cent of propane, and, burned in the same way as ethane, gave 53·91 candles as its illuminating power. Hence this value appears to be proportional to the number of carbon atoms in the molecule.—*J. Chem. Soc.*, xlvii, 235, April, 1885. G. F. B.

6. *On the Illuminating power of Methane.*—WRIGHT has made a series of experiments to determine the illuminating power of pure methane. The gas was prepared by Gladstone & Tribe's

method, by the action of the copper-zinc couple on methyl iodide, and was passed through three copper tubes 12 inches long, 1·5 inches in diameter, placed horizontally, fitted with corks and connecting glass tubes and filled with copper-zinc and as much alcohol as they would contain in this position, to remove the vapor of the iodide; and then through a glass tube containing beads moistened with sulphuric acid to absorb the alcohol vapor. The methane was collected in a small gas-holder 5 liters in capacity graduated to 5 c. c. and passed thence to the photometer, which was furnished with a Methoen standard giving a light of two candles when supplied with eighteen candle gas. The methane was burned in a London argand with a six-inch chimney, provided at top with a metal cap capable of vertical adjustment by a screw. This cap is to limit the air supply and is necessary at low rates of consumption. Two specimens of marsh gas were tested. In the first 2·78 cubic feet (corrected) were consumed per hour and gave a light of 2·9 candles; or 5·2 candles per cubic foot per hour. In the second 4·56 cubic feet were consumed per hour, giving 4·6 candles; or 5·15 candles per cubic foot per hour.—*J. Chem. Soc.*, xlvii, 200, April, 1885. G. F. B.

7. *On Toughened Filter-papers.*—Francis has observed that filter paper is remarkably toughened by the action of nitric acid, the product being pervious to liquids and quite different from parchment paper made with sulphuric acid. By immersing the paper in, or even by moistening it with, nitric acid of density 1·42 and subsequent washing, the result is attained. The toughened paper can be used like ordinary paper, filtration being but little retarded. It may be rubbed without injury, like a piece of cloth. To compare its strength with that of ordinary paper, a strip of Swedish paper 25mm. wide was made into a loop and the ends held in a vertical clamp. A glass rod was passed through the loop and from its ends a scale pan was suspended. The paper after wetting broke with a weight of 100 to 150 grams, while the same paper after the above toughening treatment supported 1·5 kilograms. Filters of this paper are very useful with the filter pump, the apex only being toughened. When treated the paper contracts slightly, filters 11·5 cm. in diameter being diminished to 10·4 cm. The ash was reduced from 0·0026 to 0·0011 gram. The treated paper contains no nitrogen, and it suffers only a slight decrease of weight.—*J. Chem. Soc.*, xlvii, 183, April, 1885. G. F. B.

8. *On a Crystallized Tricupric sulphate.*—The basic copper sulphates hitherto known have been in general amorphous powders of doubtful purity. Shenstone has now prepared a crystalline basic copper sulphate artificially. In the course of experiments on the solubility of salts in water at high temperatures, he observed in the tubes in which copper sulphate and water had been heated deposits of bright green crystals. By heating the crystals of ordinary copper sulphate $CuSO_4(H_2O)_5$ at about 200° for a few hours in tubes containing a few grams of the salt, he was

able to prepare the new salt in larger quantity. By draining off the mother liquor while still hot, and washing the solid part of the contents of the tubes with water, a green product consisting of crystalline fragments was obtained, about 0·25 gram being yielded for each tube. On analysis, the salt afforded 26·98 per cent of SO_4 and 54·49 of Cu; giving the formula of a tricupric sulphate $CuSO_4 (CuO)_2(H_2O)_2$ or $Cu_3SO_6(H_2O)_2$, which requires 53·75 per cent Cu and 27·07 SO_4. The salt is permanent when heated in the air to 190°, is insoluble in water, soluble in dilute sulphuric acid. The crystalline form was determined by Miers to be orthorhombic.—*J. Chem. Soc.*, xlvii, 375, June, 1885.

G. F. B.

9. *On the Molecular Weight of liquid Water.*—Thomsen has called attention to the fact that the conclusion reached by Raoult in his researches on the freezing point of saline solutions, that water possesses, in the condition of liquid, twice the molecular weight which it has in the condition of vapor, coincides with the conclusion to which he himself had come from his investigations on the constitution of hydrated salts. In his thermochemical researches, Thomsen says: A glance at the table of heat of hydration of hydrated salts shows that the water molecules enter often in pairs with the same heat-change; a fact explicable either by supposing that the molecules of water are symmetrically placed in the molecule of the salt, or, and perhaps more probably, that the molecular weight of liquid water is twice that of water vapor. The similarity of these conclusions, from widely different fields of investigation, is noteworthy.—*Ber. Berl. Chem. Ges.*, xviii, 1088, April, 1885. G. F. B.

II. Geology and Mineralogy.

1. *The volcanic nature of a Pacific island not an argument for little or no subsidence.*—In the remarks on this point in § 13 (p. 100) of my paper on the Origin of coral reefs and islands, I refer to the great depths found in the ocean by soundings in the vicinity of Hawaii, and speak of the facts as favoring the idea of more subsidence about that southeastern end of the group than along the northwestern, although the latter is the coral island end. Another example of similar character, but more striking, is afforded by the region of the Ladrones. This north-and-south range of islands has its largest volcanic islands in the southern part, and dwindles in the opposite direction to islands which are little more than tufa cones; and 200 miles south of Guam, the largest island, the Challenger found a depth of 4,475 fathoms (26,850 feet), one of the deepest regions of the ocean. It hence may be that Guam, like Hawaii, is a large island, not because of small subsidence, but because of continued eruptions that made it large in spite of the sinking that was in progress. The question arises how far the depths in these particular cases are due to the undermining effects of volcanic eruption. There are coral

islands both northeast of the deep region, near Guam, and also of large size, to the southwest and southeast, not three degrees off; the former, those of an extension of the Pelew range, and the latter, islands of the Caroline Archipelago. J. D. DANA.

2. *The Physical Features of Scotland*, by Professor JAMES GEIKIE.—This excellent paper is illustrated by an orographic map of Scotland which is necessary to its full appreciation. The author condemns the "statement so frequently repeated in class-books and manuals of geography, that the mountains of Scotland consist of three (some say five) ranges." He observes that it is divided into three parts "the Highlands," the Central Lowlands and the Southern Uplands; and defines the Lowlands (which are the southern limits of the Highlands and northern of the Southern Uplands) as extending from Stoneham in a nearly straight southwest direction along the northern outskirts of Strathmore to Glen Artney, and thence through the lower reaches of Loch Lomond to the Firth of Clyde at Kilcreggan. The mountains "are merely monuments of denudation," "relics of elevated plateaus which have been deeply furrowed and trenched by running water and other agents of erosion." The straightness of the southern boundary of the Highlands "is due to the fact that it coincides with a great line of fracture of the earth's crust; on the north side are hard and tough slates and schists, on the south sandstone strata prevail." Looking across Strathmore from the Sidlaws or the Ochils, the mountains seem to spring suddenly from the low grounds at their base, and to extend northeast and southwest as a great wall-like rampart. "The mean height of the Highlands above the sea is probably not less than 1500 feet;" peaks rise to a height of nearly 3500 feet. Any wide tract of this Highland region "viewed from a commanding position looks like a tumbled ocean in which the waves appear to be moving in all directions. But the masses are broad, generally round-shouldered, often somewhat flat-topped, with no great disparity of height among the dominant points. The relationship and the forms are the result of denudation; the mountains are "monuments of erosion,"—they are the wreck of an old table land—the upper surface and original inclination of which are approximately indicated by the summits of the various mountain masses and the directions of the principal water-flows.

A similar general conclusion is drawn from the Southern Uplands; that "the area is simply an old table-land furrowed into ravine and valley by the operation of the various agents of erosion."

In view of such facts it is not surprising that Scotch valleys and mountains should have given to Hutton right ideas on mountain sculpturing, and have led him to the opinion he brings out in his memoir on the Theory of the Earth (R. Soc. Edinb. 1778, and 8vo, 1795), that mountain forms are due to subaerial denudation after an elevation of a region by the earth's central heat.

Professor Geikie illustrates the subject with much interesting

detail, and discusses also other points connected with the physical history of the region. He speaks also of the shaded sheets (maps) issued by the Ordnance Survey as reproducing with marvelous skill the surface features of the country even to minor points of glacial origin; and asks in conclusion: "With such admirable cartographical work before them, how long will intelligent teachers continue to tolerate those antiquated monstrosities which so often do duty as wall-maps in their school-rooms."

3. *Pennsylvania Geological Survey.* — This Survey has recently issued the following reports:

Report on the Coal Mines of the Monongahela River Region, from the West Virginia State-line to Pittsburgh, including the mines on the Lower Youghiogheny River (No. K 4), by J. SUTTON WALL. Part I. Description of the Mines, 232 pp., 8vo, with maps and plates. Harrisburg, 1884.

Report on Perry County (No. F 2), by E. W. CLAYPOLE. 438 pp., 8vo, with many plates, maps and sections—a geological report preliminary to an account of the Paleontology. Harrisburg, 1885.

Atlas of the Northern Anthracite field, Part I (No. A A).

Maps and charts of the Report on Cameron, Elk and Forest Counties (No. R R).

Grand Atlas, Division III. Petroleum and Bituminous Coal Fields, No. I.—The first part issued of this "Grand Atlas" of the Geological Survey of Pennsylvania was noticed on page 340 of the last volume of this Journal. The Atlas is to appear in five Divisions. Division I is to contain the geological maps of the counties constructed on a scale of two miles to the inch, and will consist of 49 sheets, covering fifty-six counties; Division II, the sheets of the Anthracite Survey, including mine sheets on a scale of 800 feet to the inch, topographical sheets on a scale of 1600 feet to the inch, cross-section sheets and columnar-section sheets, besides miscellaneous sheets; Division III, of which Part I has recently been issued under the above-mentioned title; Division IV, topographical maps from the surveys of A. E. Lehman, of the South Mountain, in Adams, Franklin and Cumberland Counties, and others of the Great Valley, between Easton and Reading, from the surveys of Messrs. d'Invilliers, Berlin and Clarke, on a scale of 1600 feet to the inch, with the contour lines 10 or 20 feet apart; Division V, the geological maps and sections relating principally to the Silurian and Devonian formations in Central Pennsylvania, and cross-sections of the Philadelphia rocks.

The maps on the Petroleum and Bituminous coal fields, making the first part of Division III, contain topographical maps, plans, cross-sections, and others, illustrating the geological structure of the oil region, the distribution of the areas, the underlying rocks down to the oil-producing sand beds in a large number of sections obtained in boring for wells, and are thus full of instruction. The general map of the oil-region, prepared by C. A. Ashburner,

which comprises Western Pennsylvania, shows that the many areas lie in a belt of country 20 to 25 miles broad, extending in a northeast and southwest direction from Allegheny County, New York, to Beaver County, Pa. The belt to the northward bends to west-northwest, and thus exhibits its parallelism to the mountain system lying to the southeastward.

An announcement accompanies the recent reports stating that they may be obtained by purchase of Mr. J. S. Africa, Secretary of Internal affairs, Harrisburg, Pa. The State has directed that they shall "be furnished at cost to all applicants."

The legislature of Pennsylvania at its late session appropriated $50,000 to continue the State Geological Survey for the years 1885 and 1886, and the Governor has signed the bill. The survey was begun in 1874, and the work remaining to be done is chiefly in the anthracite coal regions. A summary of the whole in a final report of one or two volumes by Professor J. P. Lesley, the chief State Geologist, a most important work is intended to complete the set of reports.

4. *Geological Survey of New Jersey*: *Report for* 1884; G. H. Cook, State Geologist.—Fine views of the remarkable locality of columnar trap in O'Rourke's Quarry, on Mount Pleasant Avenue, Orange, make a frontispiece to this year's Report. The most singular feature is the obliquity of the columns in divergent directions about the center of the quarry while nearly vertical elsewhere. The nearly vertical columns are large, some 6 or 7 feet in diameter while the oblique are small. The columnar surface exposed has a length of about 700 feet and a height of 20 to 100 feet; and underneath it, 6 to 8 feet below the exposed surface, there lies the red sandstone. The outer surface of the columns is horizontally banded, but there is no regular cross-fracturing. Professor Cook suggests that after the main extrusion of trap, there may have been a later outflow along the central part where the small divergent columns occur. The locality may be reached by going out on Pleasant Avenue in Orange about a mile from the railroad station, and then following the quarry wagon road on the left for 400 or 500 feet.

An interesting exhibition of a buried forest is reported as recently opened at the Earnst Clay pits in South Amboy. The burial must have taken place since the settlement of the country, not more than 280 years ago; the place until recently has been under a swamp and a forest of cedars. "The ground which was formerly enough above the sea-level to sustain a growth of upland timber, is now so low that every high tide could cover it with salt water."

Artesian wells have proved to be a success along the low coast region of Southern New Jersey. Abundant pure water has been thus obtained at Ocean Grove, Asbury Park, Red Bank, Ocean Beach, Lakewood, Marlton and other points. Each passes down to the sandy stratum under the Lower Marl bed of the Cretaceous. The wells at Red Bank and Marlton have a depth between

80 and 90 feet. That at Ocean Beach, Monmouth County, about 400 feet from the ocean, is 485 feet deep, is 3 inches in diameter inside of the wrought iron casing pipe, and soon after completion yielded 36,000 gallons a day; that at Lakewood is 475 feet deep. The Lakewood water contains but 6½ grains of solid matter to the gallon.

An artesian well at Newark went down through 110 feet of earth and 505 feet of red sandstone; the bore was 8 inches in diameter and the daily yield 800,000 gallons; the temperature 55½° F. The amount of mineral matter is about 150 grains to the gallon, over two-thirds of which is calcium sulphate (gypsum). An analysis, made in 1879, afforded sodium sulphate 15·94, magnesium sulphate 25·87, calcium sulphate 106·98, magnesium carbonate 1·55, sodium chloride 2·47 = 152·81. In a trial in 1882 the amount of solid matter was found to be 151·79 grains per gallon, and in 1884 148·83 grains.

The above are a few of the facts to be found in the Report.

5. *Contributions to the Knowledge of the Older Mesozoic Flora of Virginia*, by W. M. Fontaine. 144 pp. 4to, with 54 plates. Washington, 1883. U. S. Geological Survey. (Received in June, 1885.)—Professor Fontaine, after a brief review of the beds in Virginia, describes the fossil plants in detail. His specimens were obtained from different openings on the Richmond belt, and from the Cumberland belt, about 30 miles west of the former. The plants were found in the layers of shale and sandstone adjoining the coal beds,—not far from the middle of the sandstone formation. In the Richmond belt there appear to be 500 to 600 feet of sandstone above and below the coal beds.

Forty-two species are described and figured. Half of them have no distinct relations to European species. Of the rest, twelve are decidedly Rhætic in their relations, and four identical with Rhætic species, while only four are Triassic in character and three of these are as closely Rhætic. Besides, eight have Jurassic relations. Professor Fontaine concludes, therefore, that the beds are probably of Rhætic age rather than Triassic, that is, of the epoch between the Triassic and the Lias. The descriptions and figures of the plants of the North Carolina Mesozoic described by Professor Emmons are reproduced in the volume and compared with those from Virginia. Professor Emmons's specimens were sought for without success. Of the thirty-nine species identified, fifteen are also Virginia species, and they point to the same age for the beds. The Cycad genus *Ctenophyllum*, of which there are four species, is highly characteristic of the Rhætic Lias. The genera *Acrosticides*, *Laccopteris*, *Cycadites*, *Podozamites* also are Rhætic, or Rhætic and Jurassic. The North Carolina fauna is much richer than the Virginian in Conifers; but this is attributed to drier conditions of growth and not to actual difference in flora.

This new volume from the U. S. Geological Survey is a worthy successor to the excellent Reports which have preceded it.

6. *Syenite and Gabbro in Essex County, Massachusetts.*—Dr. M. E. WADSWORTH has an article on this subject in the Geological Magazine for May last. It describes the coast from Salem to a point beyond West Manchester as occupied by a typical reddish or grayish syenite. The granite of the same region, according "to the preponderance of evidence, is the younger rock, unless it is cotemporaneous with the syenite." A gneissoid schist on Woodbury's Point contains "gabbro" in masses—called "irregular dikes"—approximately parallel to the foliation of the schist. The "gabbro" varies from a whitish rock consisting of feldspar with "a few grains of diallage" to one in which the feldspar and diallage are in nearly equal proportions, and in some of it the latter ingredient is in individuals two or three inches long. Zircon-syenite similar to that of Marblehead occurs also on Salem Neck, containing sodalite and elæolite.

7. *Thermal effect of the action of aqueous vapor on feldspathic rock (kaolinization).*—Dr. CARL BARUS discusses this question mathematically, after some careful experiments, in a paper published in the School of Mines Quarterly, November, 1884. A definite result was not reached; yet the discussion is one of much interest, as the author states in conclusion, "showing in how far very small increments of temperature, increasing continuously, through infinite time, are accurately measurable;" and "containing the first direct attack upon physical problems of this character, many of which have an important bearing on geological and metallurgical subjects."

8. *New localities of Erythrite;* by WM. P. BLAKE. (Communicated.)—There are two localities of *erythrite* in the West which deserve mention. One of these, lately opened near Lovelock's station on the Union Pacific Railway in Nevada, has yielded considerable quantities of nickel and cobalt ore. The cobalt bloom occurs in crusts and aggregations of very small crystals in the seams of a calcareous rock, containing also brilliant brass yellow acicular crystals of millerite. The ore as mined and shipped contains an unusually high percentage of both nickel and cobalt. There are also masses of a black earthy aggregate consisting largely of black oxide of cobalt. These masses do not appear to carry manganese oxide in any appreciable quantity and can not properly be referred to the ores of manganese, as with asbolite, but are rather entitled to a separate place as black oxide of cobalt, for which the name "asbolite" may be retained if the description is amended so as to make the presence of manganese unessential.

The other locality is in Los Angeles County, California, at the Kelsey Mine, Compton, where the erythrite is associated with an ore of silver and of cobalt in dark-colored earthy masses in a gangue of heavy spar. This occurrence was noted in 1881 and is described in the Report of the State Mineralogist of California for 1882, p. 207, and in the fourth report, p. 179.

III. Botany.

1. *A Course of practical instruction in Botany*, by F. O. Bower and S. H. Vines, Part I. (Macmillan & Co., London, 1885.)—This handy book of only 226 pages; is the best introduction in English to the practical investigation of flowering plants and ferns. After giving a chapter on the preparation and effects of reagents for microscopic use, the authors deal with the microchemistry and microphysics of the vegetable cell. The student is led along slowly and safely over the least attractive part of the field, and is there shown sound methods for the examination of organs of the higher plants. Nearly all of the methods are described concisely, yet so as to leave no important point untouched. Theoretically it would be better to show a student how to examine any object, and then demand of him direct answers as to what he sees, rather than to tell him what he ought to see. But this plan consumes more time than most beginners have at their command; therefore the "personally conducted" plan is generally most in vogue. The present work tells the student all that he can be reasonably expected to see under the microscope, *if* he is successful in making his sections, etc. Therefore, the student who follows out faithfully all the exercises laid down in this work may be sure of acquiring the essentials of histology, so far as the higher plants are concerned. A second volume, devoted to the plants lower than the ferns and their allies is promised. With Strasburger's German treatise, "Das botanische Practicum," or with this excellent English work as a guide, the student can have no excuse for lack of practical acquaintance with histological manipulation.

G. L. G.

2. *Text-book of Structural and Physiological Botany*, by Otto W. Thomé and Alfred W. Bennett. (Longmans, Green & Co., London, 1885.)—This is the fifth edition of a useful book. The revision brings portions of the treatise fairly down to the eve of publication, and makes it a well proportioned treatise. It is, however, a text-book, in the strictest sense of the term, and in no way supplies the help in practical manipulation which is afforded by the work noticed above. The student preparing for an examination finds that Thomé gives in small compass exactly the information required by the question-papers set in the earlier examinations for the degrees of M.B. and B.Sc. To the general student, the chapters on the geographical distribution of plants and on fossil plants are especially useful. G. L. G.

3. *Le Potager d'un Curieux: Histoire, Culture, et Usages de 100 Plantes comestibles peu connues ou inconnues.* Par A. Pailleux et D. Bois. Paris, Libraire Agricole de la Maison Rustique; pp. 294, 8vo. 1885.—This volume is a reprint from the *Bulletin de la Société Nationale d'Acclimatation.* One of the authors is a councillor in that society, the other is an assistant in the Museum at the Garden of Plants. The now classical volume of Alphonse de Candolle treats of the esculent plants of large

cultivation and investigates their history and origin. This book treats of a hundred less known or only locally known alimentary plants, records the results of trials in cultivating a considerable number of them, indicates those which promise well, and tells us how they may best be cooked. It aims to extend the domain of *l'horticulture potagère* in Europe by introductions from foreign parts of plants which various people regularly use for food, trusting that some of them may prove to be valuable acquisitions. Let us note, as having for us a certain interest, the North American plants which our authors take into consideration. They are *Apios tuberosa*, which was vaunted as a most hopeful substitute for the potato in the days of potato-rot in France, but which, naturally came to nothing, which, indeed, would never have been thought of except for the tradition of its use by the aborigines of New England. *Camassia esculenta*, the *Quamash*, upon the bulbs of which the Indians of Oregon were largely nourished. Introduced into France, these bulbs were pronounced to be a dainty dish; but our author's attempts to cultivate them on a large scale completely failed. *Claytonia perfoliata*, which, as a succedaneum for spinach in summer, is said to furnish "un aliment acceptable." *Melothria pendula*, the berries of which have been highly recommended for pickles! Naturally our authors do not recommend them. *Phytolacca decandra*, the spring shoots just pushing from the ground, used in the manner of asparagus, so used indeed in some parts of the United States. It seems that of late they have been largely supplied to the Paris market. M. Paillieux reports that some people seem to like them, that he finds them rather tasteless, and that he has eaten them, in small quantity indeed, without any ill effects. Probably the largest use of our Poke in France is for the rich coloring matter of the berries in wine-making. *Psoralea esculenta*, of the Upper Missouri region, the tuberous roots of which, being very farinaceous, were introduced into France, forty years ago, to be a substitute for the failing potato, but which, as might have been expected, proved an utter failure. In fact the contributions of North America to the kitchen-garden (deduction made of *Helianthus tuberosus*) amount to nothing. The authors of this work evince a wonderful hopefulness by asking (in a private communication) to be supplied with the means for making trial of some other Indian food plants, such as *Lewisia*, the tuberous-rooted species of *Callirhoë*, *Balsamorrhiza* and *Peucedanum*, *Valeriana edulis*, etc. They even ask for *Asclepias tuberosa*. This reminds us that—judging from the recollections of boyhood—the verual shoots of *Asclepias Cornuti*, our common milk-weed, make the best of substitutes for asparagus.

More important plants than these, mainly from tropical or subtropical regions, are reported on in this book, some of them, such as the various kinds of Yam, at full length. The volume is rather a series of reports, than a treatise. The practical and also truly scientific work is Vilmorin's Plantes Potagères. A. G.

4. *Contributions to American Botany*, XII; by SERENO WATSON. Extr. Proc. Am. Acad., xx. Feb. 21, 1885, pp. 324–374, with a full index.—This last particular is one of the good points of Dr. Watson's papers, an extra finish which botanists are thankful for, none the less because they cannot generally expect it. A most important "contribution" indeed, one in which the essential results of very prolonged study and critical toil are condensed into less than thirty pages, is the *History and Revision of the Roses of North America.* The "History" any one can read with interest; the "Synopsis of Species" (18 in number, which European treatment might have quadrupled, and which "the extreme of possible reduction" might condense into nine) presents the botanist with a convenient view of the leading differential characters; then we have, under proper divisions, sufficiently detailed descriptions, habitat, and a particular mention of localities and collectors. Thanks to our botanists and curators, nearly all the principal herbarium-material in the country was in the monographer's hands, and a part of that in the Gray herbarium had previously been examined by Crépin in Belgium. Let us hope that our Roses may now be fairly well and readily understood by our botanists, that the attention which, with such help, they will generally receive may lessen rather than increase the remaining doubts and ambiguities, and that this judicious monograph may do its part in preserving our American rhodology from the fearful state which that of the Old World presents.

The other article of the present contribution consists of "*Descriptions of some New Species of Plants, chiefly from our Western Territories,*" which have recently been brought to light by our various zealous collectors, and which are examined in the course of preparation of the Flora of North America. A few already published plants are mentioned. Among them is *Atamisquea emarginata* of Miers, a rare Capparideous shrub of a peculiar genus, which Miers discovered in the province of Mendoza, in about the same latitude in the southern hemisphere that Mr. Pringle found it in the northern, namely in the northwestern borders of the Mexican State of Sonora. As far as we can see there is no difference between the specimens from these widely disjoined stations, the only two known. Dr. Kellogg's *Œnothera arborea*, which he long ago figured in the Hesperian is taken up and described aright as *Hauya Californica.* It would have been better to follow the general rule of retaining the original specific name, and also to have avoided "Californica." For, although the country which this shrub inhabits was the original California, it is not our California.

Tetracoccus, the only new genus described in this paper is interesting as being the last plant studied and named by Engelmann. It was discovered by Dr. Parry in Lower California, in the winter of 1883, but male flowers and mature fruit were obtained by his young friend, Charles R. Orcutt, a year and a half later. Both sent materials to the Gray Herbarium, and it was supposed that

it was left to be published from here. But meanwhile Dr. Parry, the discoverer, thought best to bring out the genus in Southern California, in Orcutt's "Western Scientist;" and so *Tetracoccus monoicus*, Engelm. and Parry, was published while the *Tetracoccus* (Engelmann) *Engelmanni*, Watson, was here in press.

It should perhaps be here noted that there is a somewhat earlier paper in the same (twentieth) volume of the Proceedings of the American Academy of Arts and Sciences, by the present writer (pp. 257–310), comprising *A Revision of some Borragineous Genera* (*Omphalodes, Krynitzkia, Plagiobotrys*), *Notes on some American Species of Utricularia, New Genera of Arizona, California*, etc., and *Gamopetalæ Miscellaneæ*. A large share of the latter, as also of Dr. Watson's Miscellaneæ, are from the interesting collections made last year by Mr. Pringle, with no small hardship and suffering, along the frontiers between Arizona and Sonora. This year Mr. Pringle, with his usual zeal and with excellent prospects, undertook the exploration of the State of Chihuahua; but when about to enter into the most alluring yet hazardous field, that of the Sierra Madre Mountains, he was prostrated by a return of last year's fever, and has been obliged to return home for recuperation. Let us hope that the air of his native Vermont will soon restore him to wonted health, and to the botanical explorations for which he is remarkably fitted, and in which he bears the palm. A. G.

5. *Talks Afield about Plants and the Science of Plants*, by L. H. Bailey, Jr. (Boston: Houghton, Mifflin & Co., 1885, pp. 173, 12mo), are pleasant talks, well adapted to inspire an interest in plants and botany, sensible and instructive in what is said, equally sensible in the omission of the technical and recondite matters which are too commonly crowded into books of this sort. A. G.

IV. Miscellaneous Scientific Intelligence.

1. *Report of the Secretary of the Smithsonian Institution*, Professor Spencer F. Baird, *for the year* 1884. 98 pp., 8vo.—The Smithsonian Institution has become a great center for the collection and diffusion of knowledge. Considering the amount of labor and investigation carried forward, the expenditure for 1884 appears very small—43,613.36 dollars out of the total income, which was 68,994.20 dollars. The explorations promoted by the institution, which have in past time done more for "increasing our knowledge of the physical condition and natural history of various parts of the globe, especially on the continent of America," than any other single agency in the land, were carried on in 1884 partly in coöperation with the U. S. Signal Service, the Geological Survey and the Fish Commission, in Greenland, Labrador, Alaska, British Columbia and Washington Territory, Arizona, New Mexico, Mexico, Central America, and other regions. The quarto volume of the Smithsonian Contributions to Knowledge, published during the year, is that of Dr. C. Rau on

"Prehistoric Fishing in Europe and North America," a work already noticed in this Journal. Not the least of the benefits conferred by the Smithson gift is the free system of international exchanges of scientific publications carried on by it. During 1884 over 65,000 packages were thus distributed, of an aggregate weight of nearly 154,000 pounds. The institution has also been a chief reliance in State and International Exhibitions and has brought great credit to the country and done it great service by its labors in this direction.

Further, the care and enlargement of the National Museum, although supported by appropriations from Congress, have become a prominent object with the institution. The grand museum is an expression of the efficiency of the present secretary, Professor Baird.

2. *American Association for the Advancement of Science.*—The arrangements made by the local committee for the coming meeting are noticed on page 87. For all matters pertaining to membership, papers, and business of the Association the permanent Secretary, F. W. Putnam, should be addressed, at Salem to August 20, and at Ann Arbor, Michigan, from August 20 to September 2.

The President of the session is H. A. Newton of New Haven, Ct.; the Vice Presidents, J. H. Van Vleck of Middletown, Ct., in Mathematics and Astronomy; C. F. Brackett of Princeton, N. J., in Physics; W. R. Nichols of Boston, Mass.; J. B. Webb of Ithaca, in Mechanical Science; B. G. Wilder of Ithaca, in Biology; S. H. Gager of Ithaca, in Histology and Microscopy; W. H. Dall of Washington, in Anthropology; and E. Atkinson of Boston in Economic Science and Statistics.

3. *Report on the Museums of America and Canada;* by V. Ball. 34 pp. 8vo.—Mr. Ball, formerly connected with the geological Survey of India, is now Director of the Science and Art Museum, Dublin. His observations on American Museums were made during his visit to the country last summer, and with special reference to the improvement of the arrangements in the museum under his charge, and not without some profit, as he states in his report.

The Sun: A familiar description of his phenomena, by the Rev. Thomas W. Webb. 80 pp. 12mo. New York, 1885. (Industrial Publication Company.)

An Introduction to Practical Chemistry, including Analysis, by John E. Bowman; edited by Charles L. Bloxam. Eighth edition. 248 pp. 12mo. Philadelphia, 1885. (P. Blakiston, Son & Co.)

An Introduction to Practical Organic Analysis, adapted to the requirements of the first M. B. Examination, by George E. R. Ellis. 72 pp. 12mo. London, 1885. (Longmans, Green & Co.)

OBITUARY.

Titian R. Peale, of Philadelphia, died on the 13th of March, 1885, in his 86th year. Mr. Peale was one of the Naturalists of the Wilkes Exploring Expedition. He was for twenty-four years connected with the Patent Office at Washington.

ERRATUM.

Page 108, 24th line from top, for August, read September 17th, at 5 P. M.

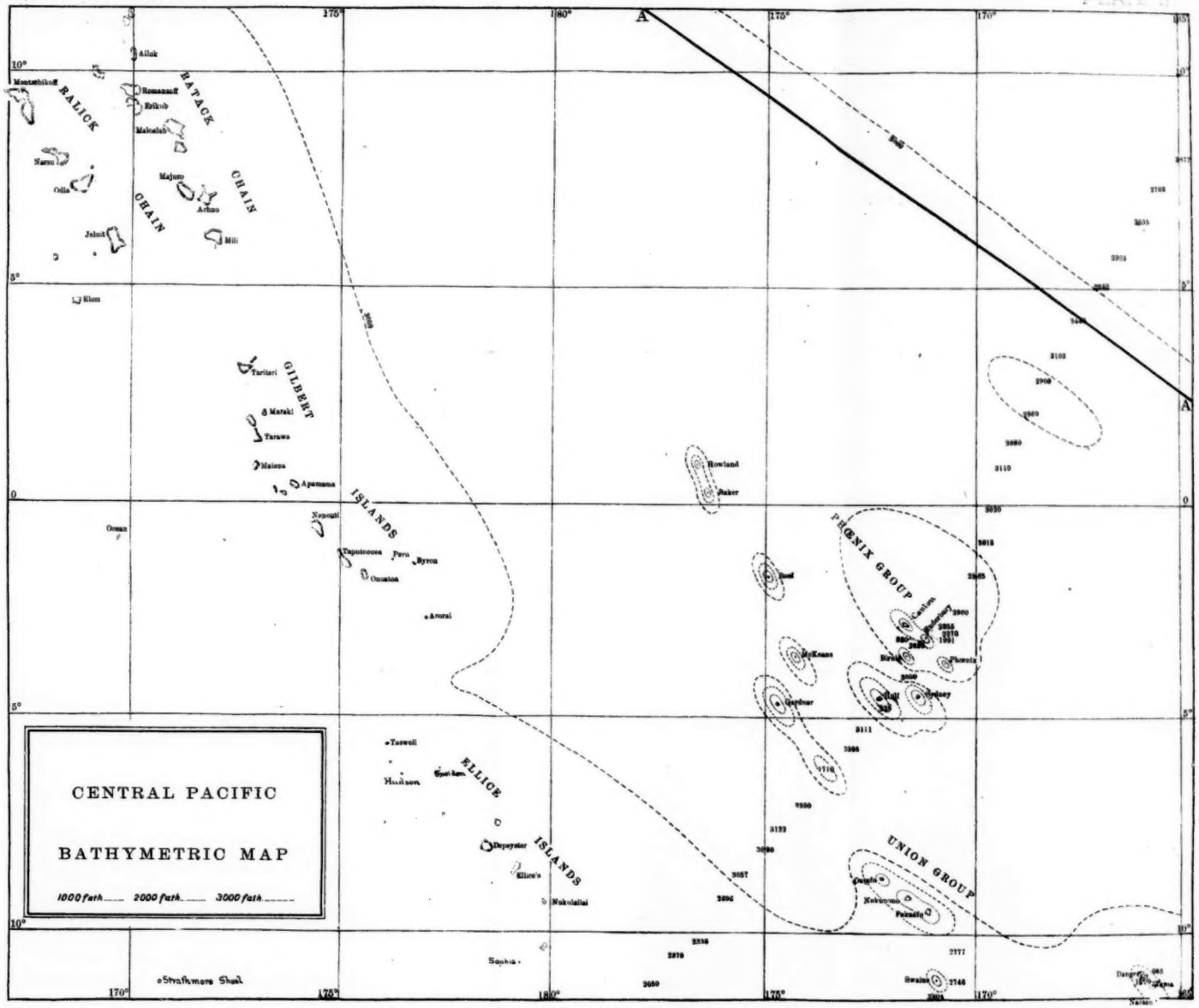

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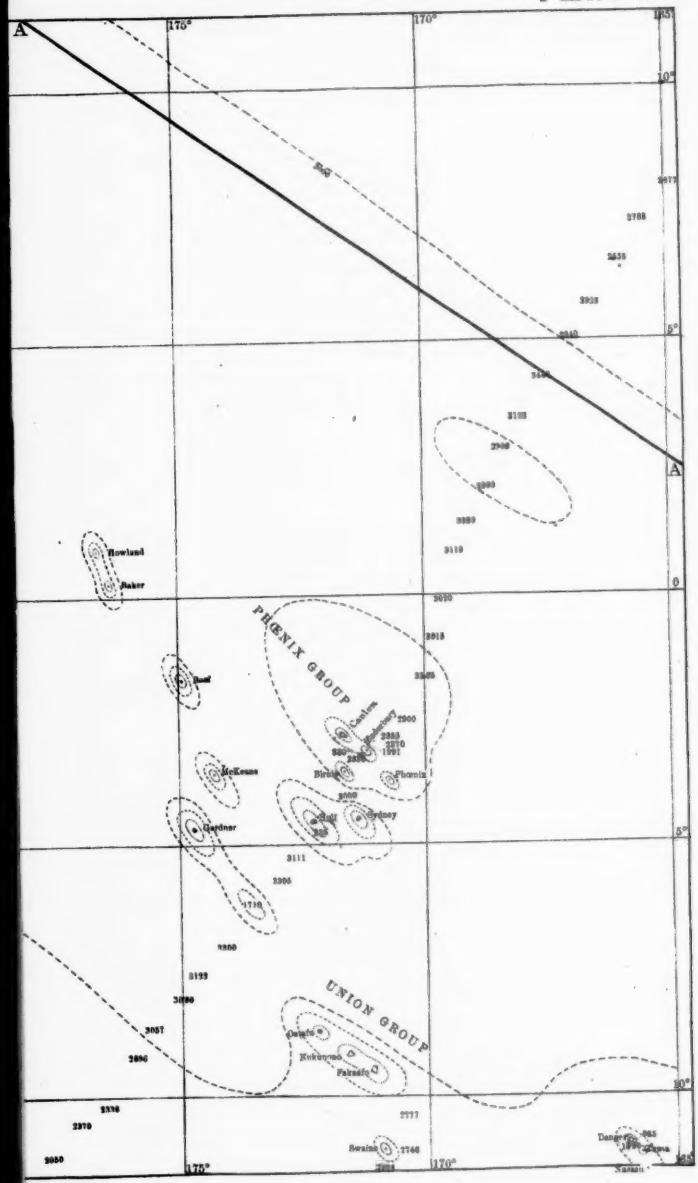
PLATE II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